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V E R S I T Ä T

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ISSPA 02

Identification of **S**tructural **S**ystem **Pa**rameters

Version ISSPA02-03

User's Guide
(extract)

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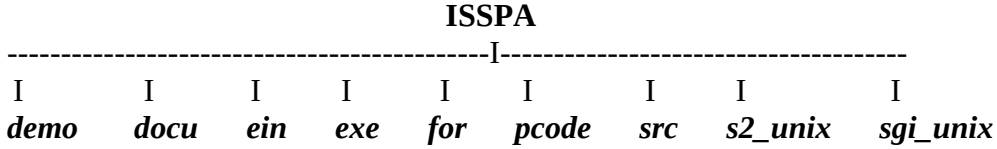
Abbreviation

MDOF	**m**easurement **d**egree **o**f **f**reedom
UKL	**U**niversity of **K**assel, Department of Civil Engineering, Laboratory of **L**ightweight Structures and Structural Mechanics
ISSPA	**I**dentification of **S**tructural **S**ystem **Pa**rameters
MATLAB	high performance numeric computation and visualization software, MATHWORKS
GUI	**g**raphical **u**ser **i**nterface
FRF	**f**requency **r**esponse **f**unction
x, y, z, xx, yy, zz	MDOF direction
U_X, U_Y, U_Z	translational MDOF
U_{XX}, U_{YY}, U_{ZZ}	rotational MDOF
F_X, F_Y, F_Z	nodal excitation forces
F_{XX}, F_{YY}, F_{ZZ}	nodal excitation forces (moments)
n, N	overall number of MDOF
r, MFG	overall number of modes
n_f	overall number of exciter forces
m	overall number of spectral lines, frequency points
$\ddot{U}_b$	base acceleration
{filename}	file not necessarily needed

1. ISSPA Installation

The software package ISSPA comprises FORTRAN executables and MATHWORKS/MATLAB command Files (m-files). The FORTRAN executables are the kernel of the identification procedure and may be called independently from any other software using simple operating system commands. A graphical user interface (GUI) has been provided to ease the application of the ISSPA modules and to produce all graphical output. The GUI is implemented into MATHWORKS/MATLAB using several MATLAB command files (*.m, or *.p). Therefore, ISSPA requires that MATHWORKS/MATLAB Version 5.3 or higher is installed on the computer (PC or UNIX workstation) if the ISSPA GUI is to be used.

ISSPA is distributed on a media using the following directory structure:



contents:

demo	ISSPA demo identification (ref. Appendix E)
docu	ISSPA documentation (Microsoft WORD 97 documents or pdf documents)
ein	Templates of ISSPA input files
exe	ISSPA FORTRAN executables
for	ISSPA FORTRAN sources
pcode	ISSPA graphical user interface (p-code)
src	ISSPA graphical user interface
s2_unix	ISSPA implementation tools for SUN/SOLARIS 2
sgi_unix	ISSPA implementation tools for SILICON-GRAPHICS

In addition the media includes the ukl\tbox **,** a special software package which includes general data handle tools which are commonly used by several UKL software packages.

To run ISSPA within MATLAB the MATLABPATH has to be extended to include the following directories:

- ukl\isspa\src or ukl\isspa\pcode\matlab*
- ukl\tbox

Note:
If only the *pcode edition* or the *limited edition* of ISSPA is available the user must link the corresponding subdirectory matlab51, ..., matlab65 of the \pcode directory to the MATLABPATH.

The user must also set the operating system program search path to include ukl\isspa\exe and ukl\tbox. Refer to the User's Manual of your computer to properly set the program search path.

Note:

Your implementation of ISSPA may differ from this general directory structure due to individual requirements.

To check the ISSPA installation it is recommend to copy the *demo* directory to a temporary working directory and start the auto sequence of demonstration examples by calling *demo_all* within MATLAB from the actual demo directory.

2. General

ISSPA is a software package for the identification of linear structural system parameters. It is developed by the 'Department of Lightweight Structures and Structural Mechanics' at the 'Department of Civil Engineering' at the 'University of Kassel, Germany' (UKL), Prof. Dr. Ing. M. Link. ISSPA comprises standalone FORTRAN executables and a graphical user interface (GUI) written using MATHWORKS/MATLAB /10/ computation and visualization software. ISSPA is aimed to be used to solve low to medium scaled problems up approx. 800 measurement degrees of freedom (MDOF) and 3200 spectral lines. The developers of ISSPA put much more emphasis on the solution algorithms and the variety of applications than on graphical user interface programming. Due to this, the user has to take a high share on specifying all needed input data correctly.
ISSPA expects the user to be a so called 'friendly user', i.e.

- he/she has a basic knowledge in mechanics and structural identification to supply the needed input data and interpret the output results
- he/she has a basic knowledge in using MATHWORKS/MATLAB

ISSPA is certainly not designed for users who want to proof how stupid software can be. Nor should the user be disappointed, if the application may fail due to erroneous input.

The software package ISSPA (**I**dentification of **S**tructural **S**ystem **Pa**rameters) consists of nine modules :

ISPMOD	Selection of identification frequency ranges
FITKOR	Curve fit identification of modal parameters and residual correction
ISPKON	Condensation of measurement matrices to effective degrees of freedom -> modified measurement
ISSPA	Identification of modal parameters from modified measurement
NOMOIS	Assembly of the inverse physical system matrices
DAMPF	Damping matrix improvement using a modal approach
ISPRES	Recalculation using identified data
FUELLEIS	Assembly of the results of different frequency ranges
ISPGEN	Calculation of dynamic responses from given modal data

The theory on which the software package is based is described in /1/,/2/,/3/,/13/,/18/. A comprehensive introduction to the theory is given in chap. 3 of this manual.

The ISSPA software package comprises two different identification procedures :

FITKOR	an identification approach based on modal parameters
ISSPA	an identification approach based on physical parameters

Both procedures share a common data basis. This data basis consists of several data files and an internal program control file. These files manage the data transfer between the modules and are generally not used or modified by the user.

To perform a FITKOR identification the following modules are used successively

ISPMOD	data preprocessing
FITKOR	identification using a simplified modal approach, residual correction
ISPRES	recalculation using identified data

To perform an ISSPA identification the following modules are used successively

ISPMOD	data preprocessing
FITKOR	residual correction
ISPKON	condensation of measurement matrices
ISSPA	identification using a physical approach
NOMOIS	assembly of inverse system matrices
DAMPF	damping matrix improvement, if required
ISPRES	recalculation using identified data

Note: if no residual correction is required FITKOR can be skipped

All control input to a module is given in a ASCII input file with a fixed filename. This filename consists of the module name and the extension **.ein*, e.g. ISPMOD.EIN. All input files (except ISPGEN.EIN) are specified using the UKL *.FR3 file specifications which is given in appendix A. Templates of the input files are given in appendix B and in the *ein* directory.
Each module creates a ASCII file which lists input data, program flow and results. The filename is fixed and consists of the module name and the extension **.aus*, e.g. ISPMOD.AUS.

In order to manage the internal data flow between the modules unformatted and formatted sequential files are created. A list of these files is given in appendix C. The files follow the UKL *.FR3, *.UR3 file specifications. They have no further relevance to the user and should be deleted after the results of an identification range are excepted. The ISSPA GUI provides the *Purge* button to properly perform this task.

In practical applications the identification of a complete measurement data set is **not** performed in a single step. Usually the overall data set is divided into several identification ranges which are identified one by one. It is recommended to use a separate directory for each identification range e.g. *b001*, *b002*, ... When the identification of each separate identification range is complete the modal parameters can be combined to an overall identification results file using the ISSPA module FUELLEIS. This combination should also be performed in a separate directory, e.g. *bcmb* . The ISSPA GUI provides on the *ISSPA START* and *ISSPA COMBINE* windows basic tools to properly perform these data management tasks.

3. Theoretical Background

Note:
The ISSPA User's Guide (extract) does not comprise chapter 3 of the original ISSPA User's Guide.

For detailed information about the ISSPA theory refer to:

[a] Link, M.:
Theory of a Method for Identifying Incomplete Matrices from Vibration Test Data,
Z. d. Flugwissenschaft und Weltraumforschung (ZFW) 9, 1985, Heft 2, 3

[b] Krätzig, Meskouris, Link:
Baudynamik und Systemidentifikation
in: Der Ingenieurbau: Grundwissen,
Band 5, Baustatik, Baudynamik, (Mehlhorn Hrsg.)
Berlin 1995, Ernst & Sohn, ISBN 3-433-01571-6

[c] Link, M.; Qian, G.:
Identification of Dynamic Models for Substructure Synthesis Using Base Excitation and Measured Reaction Forces.
Revue Francaise de Mecanique, No. 1 (1994)

[d] Kasai T. and Link M.: Identification of Non-Proportional Modal Damping Matrix and Real Normal Modes. Mech. Systems & Signal processing, Vol. 16, No 6, 921- 934, (2002)

4. ISSPA Input Features

The ISSPA identification procedure is based on the linear equation of motion in the frequency domain. Therefore the basic ISSPA input features can best be explained by the frequency response relation

$$\underset{(n,1)}{\ddot{\mathbf{U}}(j\omega)} = \underset{(n,n_f)}{\mathbf{H}(j\omega)}\underset{(n_f,1)}{\mathbf{F}(j\omega)} \tag{4.01}$$

where

n = no. of measured degrees of freedom (MDOF)

n_f = no. of exciter forces ($n_f \le n$)

$\boldsymbol{\omega}$ = excitation frequency

$j = \sqrt{-1}$ imaginary unit

$$\underset{(n,n_f)}{\mathbf{H}} = -\omega^2\left(-\omega^2\mathbf{M} + \mathbf{K} + j\omega\mathbf{D}\right)^{-1} \tag{4.02}$$

= nf columns of matrix of frequency response functions (inertance) w.r. to the complex exciter force vector $\mathbf{F} = [F_1 \ldots F_k \ldots F_{nf}]^T$

M, **K**, **D** = physical mass, stiffness and damping matrix

$\mathbf{U} = [U_1 \ldots U_n]^T$ measured complex frequency acceleration response at n MDOF

The user must supply measured frequency acceleration response $\ddot{\mathbf{U}}(j\omega)$ and forcing function $\mathbf{F}(j\omega)$ as input to the identification procedure. The type and amount of input depends on the type of the identification problem. Refer to app. A-C for detailed input and output file specifications.

Case I :

Constant harmonic (sinusoidal) force excitation with n_f exciter forces

(ISSPA control parameters IHARMO = 1, IFUSS = 0)

Input

a) force vector $\mathbf{F} = [\ F_1 \ldots F_k \ldots F_{nf}\ ]^T$
   real part $\mathbf{F}^{re} = \mathbf{F}$ = const. for all excitation frequencies $\boldsymbol{\omega}$
   imaginary part $\mathbf{F}^{im} = 0$
b) response $\ddot{\mathbf{U}}(j\boldsymbol{\omega})$ (equivalent to $\mathbf{H}(j\omega)\,\mathbf{F}$)

Output

a) eigenfrequencies, eigenvectors, modal masses, modal damping factors
b) inverse physical stiffness and mass matrix (incomplete)

Special case

FRF data provided by a standard data acquisition unit using e.g. a single shaker or a modal impulse hammer:
Single point excitation at MDOF k with force $F_k = 1$. In this case the response is equivalent to the k-th column of the frequency response functions (FRF matrix):

$$\ddot{\mathbf{U}}(j\boldsymbol{\omega}) = \mathbf{H}_k(j\boldsymbol{\omega})$$

Note

If more than one exciter configuration was used for testing (like in classical modal survey testing with force appropriation) the test data must be analyzed separately for each configuration.

Case II :

Harmonic constant single axis base acceleration

(Data preparation outside ISSPA necessary, case II is thereby reduced to case I)
ISSPA control parameters IHARMO = 1, IFUSS =0)

It is assumed that the following basic data is available (ref. fig. 4.1):

- the measured acceleration frequency response of *N* degrees of freedom (MDOFs) well distributed on the structure to gain a sufficient spatial resolution. The responses are measured at *m* frequency points (spectral lines).
- the measured acceleration frequency response of the pilot accelerometers mounted on the rigid interface shaker/structure.
- if available: measured reaction forces (i.e. measured by a force measurement device /15,/17/)
- if available: the mass matrix of a FE model reduced to *N* MDOFs

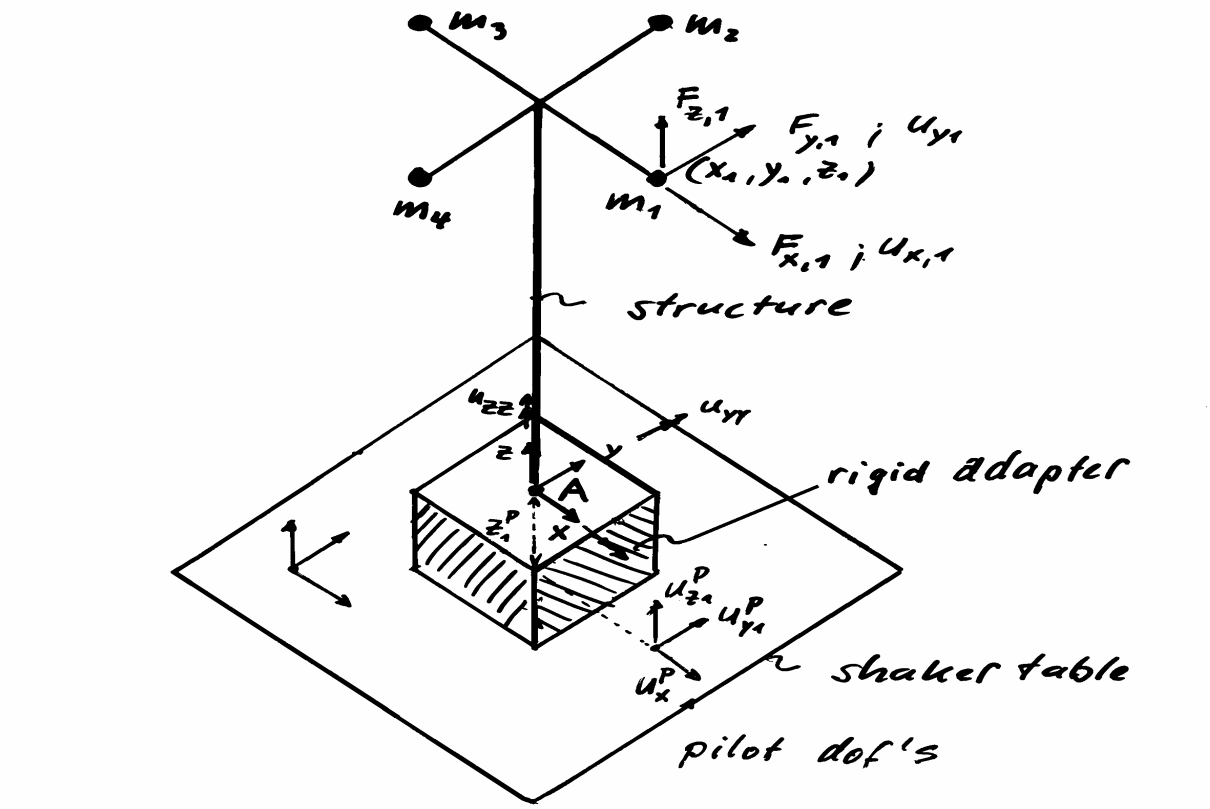


Fig 4.1: Typical test configuration used in base excitation testing

There are three basic steps necessary to prepare the measured data from a sine base excitation test for the ISSPA identification procedure

1. Calculation of the base excitation at reference (A) from the pilot pickups
2 Calculation of the relative response at the structural MDOFs with respect to the base (A)
3 Definition of excitation forces

Note: All steps must be performed outside ISSPA, prior to an ISSPA identification.

1. Calculation of the base excitation at reference (A) from the pilot pickups

In base excitation testing, there are a number of pilot pickups mounted on the shaker table. During test they are used as a part of the shaker control system. For the subsequent identification process they provide all necessary information to calculate the applied base excitation with respect to the mounting point of the test structure (point (A) in figs 4.1 and 4.2).

If the adapter and shaker table is rigid the relation between the pilot responses $\mathbf{U}^{p}(\omega)$ and the base excitation $\mathbf{U}^{A}(\omega)$ is given for each excitation frequency ω by

$$\underbrace{\begin{bmatrix} \vdots \\ u^{p}_{x_i} \\ u^{p}_{y_i} \\ u^{p}_{z_i} \\ \vdots \end{bmatrix}}_{\mathbf{U}^{p}} = \underbrace{\begin{bmatrix} . & . & . & . & . & . \\ 1 & 0 & 0 & 0 & z^{p}_{i} & -y^{p}_{i} \\ 0 & 1 & 0 & -z^{p}_{i} & 0 & x^{p}_{i} \\ 0 & 0 & 1 & y^{p}_{i} & -x^{p}_{i} & 0 \\ . & . & . & . & . & . \end{bmatrix}}_{\mathbf{T}^{p}} \underbrace{\begin{bmatrix} u^{A}_{x} \\ u^{A}_{y} \\ u^{A}_{z} \\ u^{A}_{xx} \\ u^{A}_{yy} \\ u^{A}_{zz} \end{bmatrix}}_{\mathbf{U}^{A}} \tag{4.1}$$

where

$u^{p}_{x_i}$	response of the i-th pilot measured in x- direction
$x^{p}_{i}, y^{p}_{i}, z^{p}_{i}$	distance of the i-th pilot location and reference (A)
u^{A}_{x}	excitation at reference (A) in x- direction
i	number of pilot pickup i = 1,2,...n_p

Since the number of pilot DOFs can be much larger than the number of excitation DOFs the pseudo inversion

$$\mathbf{U}^{A} = \mathbf{T}^{p^{+}} \mathbf{U}^{p} \tag{4.2}$$

where

$\mathbf{T}^{p^+}$ pseudo inverse of $\mathbf{T}^p$

relates the base excitation $\mathbf{U}^A$ and the measured pilot responses $\mathbf{U}^p$ in a least squares sense.

Example:

Determination of base excitation in X/Z- plane at reference (A) from 4 pilot MDOFs

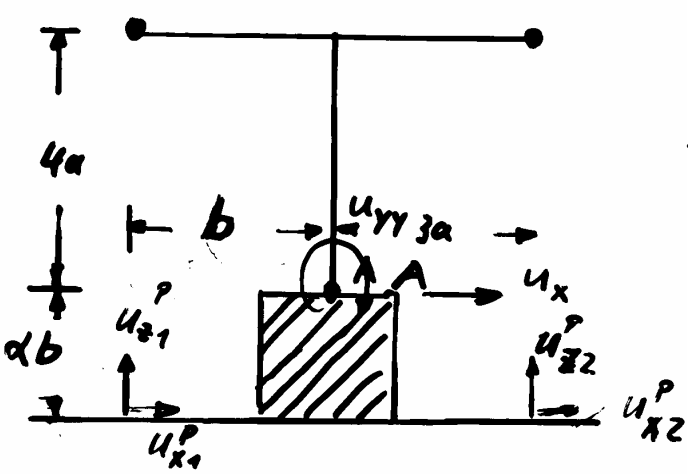


Fig 4.2: Base excitation in X/Z plane

Eq. (4.1) yields

$$\begin{bmatrix} u^p_{x_1} \\ u^p_{z_1} \\ u^p_{x_2} \\ u^p_{z_2} \end{bmatrix} = \underbrace{\begin{bmatrix} 1 & -\alpha b \\ 0 & b \\ 1 & -\alpha b \\ 0 & -b \end{bmatrix}}_{\mathbf{T}^p} \begin{bmatrix} u^A_x \\ u^A_{yy} \end{bmatrix} \tag{4.3}$$

The pseudo inverse of $\mathbf{T}^p$ is given by

$$\mathbf{T}^{p^+} = \left(\mathbf{T}^{p^T} \mathbf{T}^p \right)^{-1} \mathbf{T}^{p^T} \tag{4.4}$$

From that, the base excitation at reference (A) can be calculated

$$U_x^A = \frac{1}{2}\left(U_{x1}^p + U_{x2}^p\right) + \alpha\left(U_{z1}^p - U_{z2}^p\right) \tag{4.5a}$$

$$U_{yy}^A = \frac{1}{b}\left(U_{z1}^p - U_{z2}^p\right) \tag{4.5b}$$

In the special case when the base rotations can be neglected

$$U_{xx}^A = U_{yy}^A = U_{zz}^A \approx 0 \tag{4.6}$$

eq. (4.2) yields

$$U_x^A = \frac{1}{n_{px}}\sum U_{x_i}^p$$

$$U_y^A = \frac{1}{n_{py}}\sum U_{y_i}^p \tag{4.7a-c}$$

$$U_z^A = \frac{1}{n_{pz}}\sum U_{z_i}^p$$

where

n_{px}, n_{py}, n_{pz} overall number of pilots in X,Y,Z

In this case the base excitation in X,Y,Z is calculated from the average of the corresponding pilots.

Note:

The actual software implementation of ISSPA requires a constant base excitation level $\mathbf{U}^A(\omega)$ with respect to the excitation frequencies ω. Therefore $\mathbf{U}^p(\omega)$ should be constant within the selected frequency range, i.e. only tests without notching should be used. However, if only data from tests are available where input notching was applied the response of the structural MDOFs $\mathbf{U}$ must be related to the base excitation by

$$\underbrace{\begin{bmatrix} U_{1x} \\ U_{1y} \\ U_{1z} \\ U_{2x} \\ \vdots \\ \vdots \\ U_{Ny} \\ U_{Nz} \end{bmatrix}}_{\mathbf{U}} = {}_{N}\begin{bmatrix} \\ \\ \\ \\ \\ \\ \\ \\ \end{bmatrix} \mathbf{H} \begin{bmatrix} \\ \\ \\ \\ \\ \\ \\ \\ \end{bmatrix}^{6} \underbrace{\begin{bmatrix} U^A_x \\ U^A_y \\ U^A_z \\ U^A_{xx} \\ U^A_{yy} \\ U^A_{zz} \end{bmatrix}}_{\mathbf{U}^A} \tag{4.8}$$

The transfer function matrix **H(ω)** contains all structural information and therefore can be used for modal identification. It can be calculated from

$$\mathbf{H} = \mathbf{U}\,\mathbf{U}^{A^+} \tag{4.9}$$

where

$\mathbf{U}^{A^+}$ pseudo inverse of $\mathbf{U}^A$

In the general case of a base excitation in 3-D space six independent data sets (test runs) are required to calculate $\mathbf{U}^{A^+}$. However, if the base excitation can be considered as a single axis excitation (e.g. $U^A_z \neq 0, \quad U^A_x = U^A_y = U^A_{xx} = U^A_{yy} = U^A_{zz} = 0$) a column of the transfer function matrix can be calculated simply from the complex division of the structural MDOFs by the corresponding base excitation, e.g.

$$\mathbf{H}_{(*,A_z)}(\omega_j) = \frac{\mathbf{U}(\omega_j)}{U^A_z(\omega_j)} \tag{4.10}$$

where

$H_{(*,A_z)}$ column of **H** with respect to a base excitation in Z direction at reference A

j number of frequency point j = 1,2,...,m

This column represents the response of the structure with respect to a unit single axis base excitation (e.g. in Z). Hence, all structural MDOFs which direction coincide with the base excitation direction must exhibit a transfer function of 1 in the low frequency range (0< ω < first elastic structural mode). This is due to the rigid body movement of the structure in this frequency range.

In the most practical case where a pure single axis base excitation is not achieved eq.(4.10) yields the transfer functions with respect to a non fixed base. In this case all other base excitation DOFs are treated as structural DOFs.

2. Calculation of the relative response at the structural MDOFs with respect to the base (A)

In the case of the transfer function matrix (eq. 4.9-10) the rigid body part must be removed from the transfer functions.

$$\mathbf{H}_{\text{rel}}^{\text{real}} = \text{H}^{\text{real}} - \text{T}^{\text{H}} \qquad \mathbf{H}_{\text{rel}}^{\text{imag}} = \text{H}^{\text{imag}} \tag{4.11a-b}$$

where

$\text{H}_{\text{rel}}^{\text{real}}, \text{H}_{\text{rel}}^{\text{imag}}$ real, imaginary part of **H** with respect to the base A

$\mathbf{T}^{\text{H}}$ rigid body transformation matrix relating the unit base displacements in excitation direction and the structural MDOFs responses

This modification effects only the real part and depends on the orientation of the structural MDOFs with respect to the XYZ coordinate system defined by the base DOFs. So in the case e.g. that the direction of a structural MDOF coincides with the base excitation direction the value 1 must be subtracted from the real part of the transfer function.

In the more general case the relative response of a structural MDOFs is given by

$$\mathbf{U}_{\text{rel}} = \mathbf{U}_{\text{abs}} - \mathbf{T}^{\text{s}}\mathbf{U}^{\text{A}} \tag{4.12}$$

where

$\mathbf{U}_{\text{rel}}$ relative response

$\mathbf{U}_{\text{abs}}$ measured response

$\mathbf{T}^{\text{s}}$ rigid body transformation matrix

$$\mathbf{T}^{\text{s}} = \underbrace{\begin{bmatrix} . & . & . & . & . & . \\ 1 & 0 & 0 & 0 & z_i^s & -y_i^s \\ 0 & 1 & 0 & -z_i^s & 0 & x_i^s \\ 0 & 0 & 1 & y_i^s & -x_i^s & 0 \\ . & . & . & . & . & . \end{bmatrix}}_{\mathbf{T}^{\text{s}}} \begin{matrix} \\ \text{i - th MDOF in X} \\ \text{i-th MDOF in Y} \\ \text{i-th MDOF in Z} \\ \\ \end{matrix} \tag{4.13}$$

x_i^s, y_i^s, z_i^s distance of i-th structural MDOF to reference (A)

Example:

Calculation of the relative response of the first structural MDOF in X direction

$$U_{x1}^{rel} = U_{x1}^{abs} - U_{x}^{A} - z_1^s U_{yy}^{A} + y_1^s U_{zz}^{A} \tag{4.14}$$

In the case that the base rotations can be neglected eq. 4.12 yields

$$\begin{aligned} U_{x_i}^{rel} &= U_{x_i}^{abs} - U_{x}^{A} \\ U_{y_i}^{rel} &= U_{y_i}^{abs} - U_{y}^{A} \\ U_{z_i}^{rel} &= U_{z_i}^{abs} - U_{z}^{A} \end{aligned} \tag{4.15}$$

Note:

Either the transfer functions $\mathbf{H}_{rel}$ or the relative displacements $\mathbf{U}_{rel}$ are used for ISSPA input.

3. Definition of excitation forces

To identify the modal masses in addition to the eigenfrequencies, mode shapes, modal damping factors the excitation forces must be known. If a special force measurement device at the junction shaker/structure is used they can be measured directly /15/, /17/. If an analytical mass matrix with respect to the structural MDOFs is available, an equivalent excitation force can be calculated for each MDOF using the reference excitation (A). In both cases all modal parameters can be calculated. However, if the excitation forces are unknown, all modal parameters except the modal mass can be calculated from the measured data.

a) **excitation forces are unknown** i.e. the interface reaction forces are not measured

In this case a dummy unit force F = 1 is applied at an arbitrary MDOF. However, the identified modal masses have no physical meaning and are just needed to scale the response in a recalculation (synthesized response using the identified data)

b) **excitation forces are calculated from an analytical mass matrix**

In this case an analytical mass matrix with respect to the *N* structural MDOFs must be available. However, this mass matrix must represent sufficiently the inertia properties of the structure.
The excitation forces are calculated by

$$\mathbf{F} = -\mathbf{M}\,\mathbf{T}^{s}\,\ddot{\mathbf{U}}_{A} \tag{4.16}$$

where

M analytical mass matrix with respect to the MDOFs
F excitation force vector
$\mathbf{T}^{s}$ rigid body transformation matrix acc. eq. (4.13)

Example:
The excitation forces for the structural MDOFs in X,Y and Z at the first measurement point with an analytical lumped mass m_1 at that point are calculated from

$$\begin{aligned} F_{x1} &= -m_1\left(\ddot{U}^{A}_{x} + z^{s}_{1}\ddot{U}^{A}_{yy} - y^{s}_{1}\ddot{U}^{A}_{zz}\right) \\ F_{y1} &= -m_1\left(\ddot{U}^{A}_{y} - z^{s}_{1}\ddot{U}^{A}_{xx} + x^{s}_{1}\ddot{U}^{A}_{zz}\right) \\ F_{z1} &= -m_1\left(\ddot{U}^{A}_{z} + y^{s}_{1}\ddot{U}^{A}_{xx} - x^{s}_{1}\ddot{U}^{A}_{zz}\right) \end{aligned} \tag{4.17a-c}$$

After data preparation of the raw base excitation test data ISSPA can be applied to identify the modal parameters

(ISSPA control parameters IHARMO = 1, IFUSS = 0)

Input

a1) force vector

$$\mathbf{F} = -\mathbf{M}\,\mathbf{T}^{S}\,\ddot{\mathbf{U}}_{A}$$

or

a2) if analytical mass matrix **M** is not available:

F = 1 dummy unit force applied at an arbitrary MDOF

b) relative response with respect to the base $\ddot{\mathbf{U}}_{A}^{rel}$

Output

a) eigenfrequencies, eigenvectors, modal damping factors
if a1) is available : modal masses

Special case

Reference

Link M.; Ulrich H.; Weiland M.:
ISSPA Guidelines, Modal Identification using Base Excitation Test Data
Laboratory of Lightweight Structures and Structural Mechanics (UKL)
Kassel, April 1999

5. ISSPA Modules

5.1: ISPMOD

Purpose

Selection of identification frequency ranges
Input of ISSPA control parameters to specify the type of identification

Input

ispmod.ein	ISSPA control parameters
	Measurement data file specification
	supported formats:
	UKL FR3 (app. A)
	UKL UR3 (app. A)
	UKL IDX (app. A)
	MATLAB mat file (app.A)
	SDRC Universal files, Type 58
	max. filename length:132 characters

Output

ispmod.aus	listing file
ispmod_01.mat	plot file
ispmod_02.mat	mode indicators

Limitations

dynamic allocation of matrix dimensions limited to overall 5.2 Million REAL*4 values
low to medium scaled problems e.g. N= 800 MDOF m= 3200 spectral lines, but
N*m < 2560000 (!)

Position in ISSPA sequence

post: none
pre: FITKOR
ISPKON

5.2: FITKOR

Purpose

Curve fit identification of modal parameters and residual correction:
eigenfrequencies, eigenvectors, modal masses, diagonal modal damping matrix

Input

fitkor.ein	FITKOR control parameters eigenfrequency iteration limit ITFMAX damping iteration limits ITDMAX Iteration start values: eigenfrequencies, modal damping factors

Output

fitkor.aus	listing file
fitkor_01.mat	plot file residual corrected response

Limitations

identification using a simplified modal approach: diagonal damping matrix (proportional damping)

Position in ISSPA sequence

post: ISPMOD
pre: ISPRES
ISPKON

3.3: ISPKON

Purpose

Singular value decomposition of the measurement matrices to determine the number *r* of effective modes in the identification range (rank of measurement matrices)
Condensation of measurement matrices to *r* effective degrees of freedom.

Input

{ ispkon.ein }	ISPKON control parameters
or interactively	
	no. of effective modes

Output

ispkon.aus	listing file
ispkon_01.mat	plot file
	modified measurement

Limitations

Position in ISSPA sequence

post: FITKOR
ISPMOD(if no residual correction is required)
pre: ISSPA

3.4: ISSPA

Purpose

Identification of modal parameters from modified measurement matrices: eigenfrequencies, eigenvectors, modal masses, non-diagonal modal damping matrix

Input

Output

isspa.aus	listing file

Limitations

Position in ISSPA sequence

post: ISPKON

pre: NOMOIS

3.5: NOMOIS

Purpose

Assembly of the inverse stiffness and mass matrices
Deletion of noise modes

Input

{ nomois.ein } NOMOIS control parameters

or interactively

no. of ISSPA mode shapes to be deleted

Output

nomois.aus listing file

Limitations

Position in ISSPA sequence

post: ISSPA

pre: ISPRES
DAMPF

3.6: DAMPF

Purpose

Damping matrix improvement using a modal approach

Input

{ dampf.ein } DAMPF control parameters

or interactively

no. of spectral lines left/right to eigenfrequency to use for improving the modal damping matrix

Output

dampf.aus listing file

Limitations

Position in ISSPA sequence

post: NOMOIS

pre: ISPRES

3.7: ISPRES

Purpose

Recalculation using identified data

Input

{ ispres.ein }	ISPRES control parameters
or interactively	
	no. of modes to be suppressed in the calculation
	include residual effects, if previously calculated by FITKOR

Output

ispres.aus	listing file
ispres_01.mat	recalculated response

Limitations

Position in ISSPA sequence

post: FITKOR
NOMOIS

pre:

3.8: FUELLEIS

Purpose

Assembly of identification results of different identification ranges

Input

fuelleis.ein	FUELLEIS control parameters

Output

fuelleis.aus	listing file
fuel.fr3	modal parameters and inverse system matrices

Limitations

Position in ISSPA sequence

post: FITKOR of single identification ranges
NOMOIS " " " "

pre: ISPRES of combined identification range

3.9: ISPGEN

Purpose

Calculation of dynamic responses from given modal data

Input

ispgen.ein	ISPGEN control parameters modal parameters, dynamic response

Output

ispgen.aus	listing file
isspa2is.ein	ISSPA data file

Limitations

Position in ISSPA sequence

post

pre:

6. Using the ISSPA GUI

6. 1 General

A graphical user interface (ISSPA GUI) has been provided to ease the application of the ISSPA modules and to produce all graphical output. The GUI is implemented into MATHWORKS/MATLAB using several MATLAB command files (*.m, or *.p). Therefore, ISSPA requires that MATHWORKS/MATLAB Version 5.3 or higher is installed on the computer (PC or UNIX workstation) if the ISSPA GUI is to be used.
To run the ISSPA GUI within MATLAB the MATLABPATH has to be extended to include the UKL\ISSPA\SRC or UKL\ISSPA\PCODE\MATLAB* and the UKL\ISSPA\TBOX directories, ref chap. 1. After MATLAB start the actual setting of the MATLABPATH can be checked at any time by pressing *path* . The user must also set the operating system program search path to include UKL\ISSPA\EXE and UKL\TBOX. Refer to the User's Manual of your computer to properly set the program search path.

The ISSPA GUI is started by pressing *isspa* on the MATLAB command window .

After pressing *isspa* the *ISSPA Plot* window and the *ISSPA Main* window become visible first. From these windows all other ISSPA windows and all ISSPA commands are accessible using the respective pulldown menus or buttons. To *exit* ISSPA use the *Mange* pulldown menu of an *ISSPA* window.

The ISSPA GUI consists of several subroutines, which are called from the ISSPA windows. Almost all variables used in the ISSPA GUI are local variables which will be cleared after an ISSPA task has been performed, so that the user has no access to any of these variables. The ISSPA GUI also uses a set of global variables which are set when the ISSPA start command *isspa* is pressed and cleared after the ISSPA *exit* command is executed. These global variables are of no further relevance to the user. You can list these variables by pressing *whos global* on the Matlab Command window after ISSPA was started.

The Matlab Command window is available at any time so that the user may perform other calculations within MATLAB (e.g. MATFEM) while the ISSPA windows are active.

All data and identification results are stored in data files, which are written in the UKL FR3 format or the MATLAB mat file format (level 1, compatible to MATLAB Version 4 and 5). Refer to app. A, C for a detailed listing of the file format and index. The user can read from these data files by using the *readfr3* command e.g.

read eigenvalues (real, imaginary part) and right and left hand eigenvectors
from the ISSPA data file *nomo12.fr3*

```
[lam_re, lam_im, Y,  X]= readfr3( 'nomo12.fr3')
```

Press *help readfr3* for detailed information about the input/output arguments of this MATLAB call.

Data from MATLAB mat files can be loaded using the *load* command, e.g.

load measurement data of the actual identification range

load ispmod01

Refer to the MATLAB User's Guide or press *help load* for detailed information about the load command.

There are several ISSPA pulldown menus available in the ISSPA windows which main contents are listed below:

ISSPA Pulldown Menus:

Manage:
- *Select Working Directory*
- *Exit ISSPA*

Plot:
- *Close Figure*
- *Keep Figure* — keep actual ISSPA plot as separate figure
- *Menubar* — on/off MATLAB Menubar
- *Select, Zoom*
  - *Zoom frequency axis graphically*
  - *Zoom off*
  - *Select MDOF*
    - *MDOF_SET_1* — user defined MDOF set
    - *MDOF_SET_2*
    - *MDOF_SET_3*
    - *all MDOF*
  - *Scan MDOF* — Display MDOF one by one
- *Scales, View*
  - *Real/Imaginary*
  - *Amplitude/Phase*
  - *Nyquist*
  - *Waterfall* — Waterfall of abs(Uim)
- *Parameter*
  - *log x*
  - *log y*
  - *log z*
  - *Rotate* — rotate subplot graphically
  - *all subplot* — display all subplots of actual figure
  - *upper subplot only*
  - *lower subplot only*

ISSPA:

Select all available frequencies	specify identification range
Select identification ranges	
- data reduction	perform automatic data reduction
Pick eigenfrequencies	
ISSPA Control	view ISSPA Control window
Run FITKOR	
Run ISSPALL	
Run DAMPF	
Run ISPRES	
EF Blowup	Mode shape animation using a MATFEM FE model (Only, if UKL\MATFEM is installed)

Tag:

Tag estimated eigenfrequencies	
Tag identified eigenfrequencies	

Window:

ISSPA Main	view ISSPA window
ISSPA Start	
ISSPA Tools	
ISSPA Control	
ISSPA Linear Identification	
ISSPA Nonlinear Identification	not activated in the actual ISSPA version
ISSPA Combine	
ISSPA Plot	
ISSPA Identification Process	
ISSPA Identification Results	

Print:

b/w Printer	**b**lack/**w**hite plot to printer
b/w Paste	**b**lack/**w**hite plot to paste buffer
*b/w *.bmp*	**b**lack/**w**hite plot to bitmap file
Paste	plot to paste buffer
**.ps*	Post script file
**.bmp*	Bitmap file

Help:

About	UKL Logo

Generally, there are 9 ISSPA windows which will be used in an identification process:

ISSPA Main
ISSPA Start
ISSPA Tools
ISSPA Control
ISSPA Linear Identification
ISSPA Combine
ISSPA Plot
ISSPA Identification Process
ISSPA Identification Results

The first six windows are used to control the identification run, whereas the later three are used to present the identification results or to log the identification process. To switch among those windows each window provides the pulldown menu *Window*. In addition, the upper six windows provide buttons in the lower part of the window to easily switch to a different window. If a certain window consists of several subwindows (e.g. *ISSPA Linear Identification*) additional buttons are also provided in the lower part of the window to switch the subwindows. The user may close or resize and reposition a window at any time. The upper six windows provide a *close* button to close the respective window.

ISSPA Plot c:\user\weiland\m ... lab\isspa\demo\fhg5\b003
Manage Plot ISSPA Tag Window Print Help
ISSPA02_01_b001 UKL Root Edition
Select Working Directory

ISSPA Release

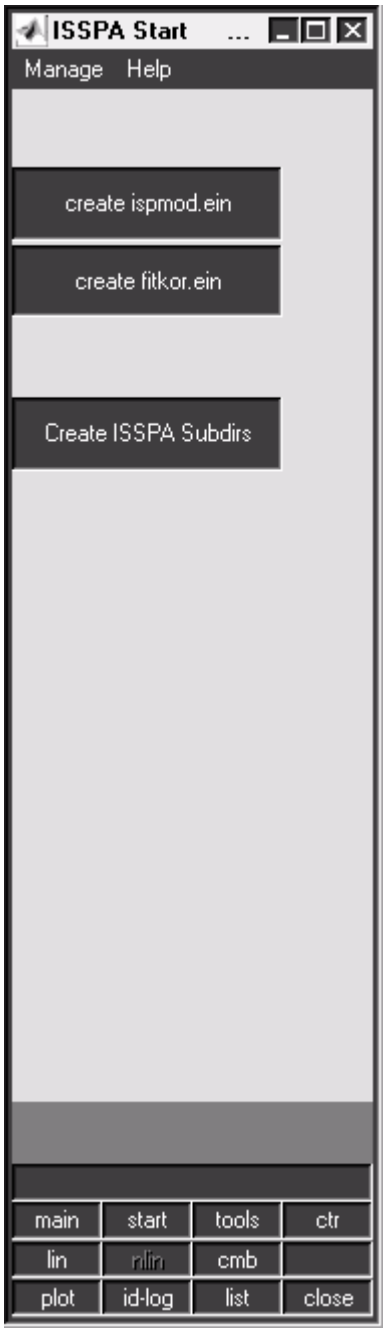
Buttons:
Select Working Directory

Fig. 6.1.1: *ISSPA Plot* window

Buttons:

main, start, tools, ctr lin, cmb, plot, id-log, list	Switch ISSPA window
close	close ISSPA Main window
Working Directory	Select working directory

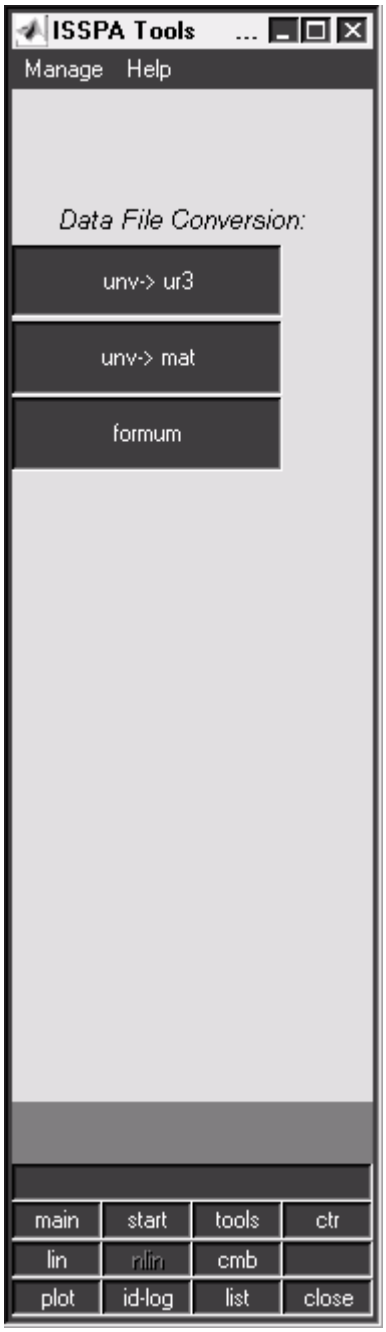
Fig. 6.1.2: *ISSPA Main* window



Buttons:

create ispmod.ein	Create/Modify ispmod.ein
create fitkor.ein	Create/Modify fitkor.ein
create ISSPA subdirs	Create ISSPA identification subdirectories *b001...b050* and the directory *bcmb* to combine identification results from identification subdirectories
main, start, tools, ctr	Switch ISSPA window
lin, cmb,	
plot, id-log, list	

Fig. 6.1.3: *ISSPA Start* window



Buttons:

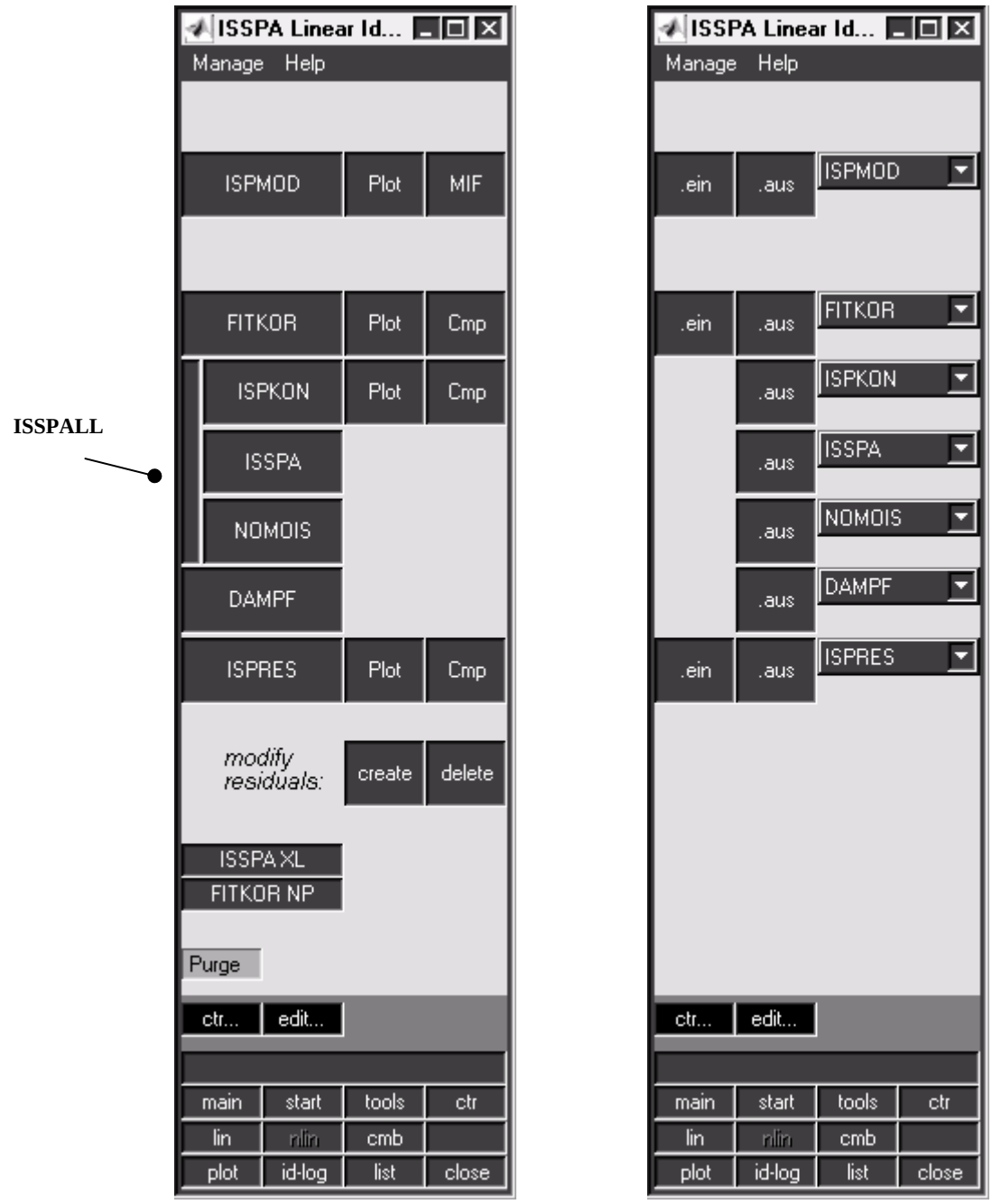
unv->ur3	Convert Universal File Type 58 to UKL UR3 File
unv->mat	Convert Universal File Type 58 to MATLAB mat File
formum	Convert UKL data files: unformatted ⇔ formatted
main, start, tools, ctr	Switch ISSPA window
lin, cmb, plot, id-log, list	

Fig. 6.1.4: *ISSPA Tools* window

Buttons:

close	Close ISSPA Control window
ISSPA exe control:	
DOS Window messages	Display channel of run time messages during an ISSPA module run
IDISP	Switch to control the amount of run time messages during an ISSPA module run
AUTORUN :	
ISPMOD	Start ISPMOD and plot data, if ISPMOD called from ISSPA pulldown menu
FITKOR	Start FITKOR after 'Pick Eigenfrequencies' was called from ISSPA pulldown menu
AUTOPLOT :	Plot after termination of module
ISPMOD	- measured response
FITKOR	- comparison of measured and recalculated response
ISSPA XL	--- for development use only ---
main, start, tools, ctr lin, cmb, plot, id-log, list	Switch ISSPA window

Fig. 6.1.5: *ISSPA Control* window



subwindow control subwindow edit

Buttons:

ctr.., edit..,	Switch ISSPA Linear Identification control or edit subwindow
main, start, tools, ctr	Switch ISSPA window
lin, cmb,	
plot, id-log, list	
close	Close ISSPA Linear Identification window

ctr..:

ISPMOD, Plot, MIF	Start ISPMOD, Plot measurement data, Plot Mode Indicator Function
FITKOR, Cmp	Start FITKOR, Plot measurement data/residual corrected data
ISSPALL	Autorun ISPKON, ISSPA, NOMOIS
ISPKON, Plot, Cmp	Start ISPKON, Plot substitute measurement data, Plot substitute measurement data/ measurement data
ISSPA	Start ISSPA
NOMOIS	Start NOMOIS
DAMPF	Start DAMPF
ISPRES	Start ISPRES, Plot recalculated data, Plot recalculated data/ measurement data

modify residuals	Modify residual terms:
create	Create residual terms after identification from the deviation of measured and recalculated response
delete	Delete residual terms

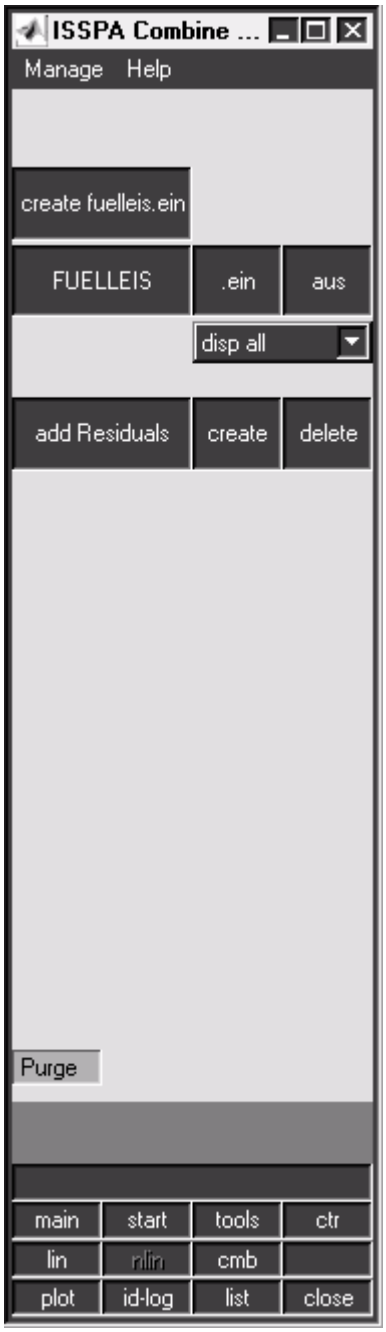
ISSPA XL	--- for development use only ---
FITKOR NP	--- for development use only ---

Purge	Delete ISSPA intermediate results

edit..:	edit or type ISSPA module input/output files
.ein, .aus, ISPMOD	Edit ispmod.ein, ispmod.aus, type ispmod.aus on MATLAB command window
...	...
...	...
...	...

main, start, tools, ctr *lin, cmb,* *plot, id-log, list*	Switch ISSPA window

Fig. 6.1.6: *ISSPA Linear Identification* window



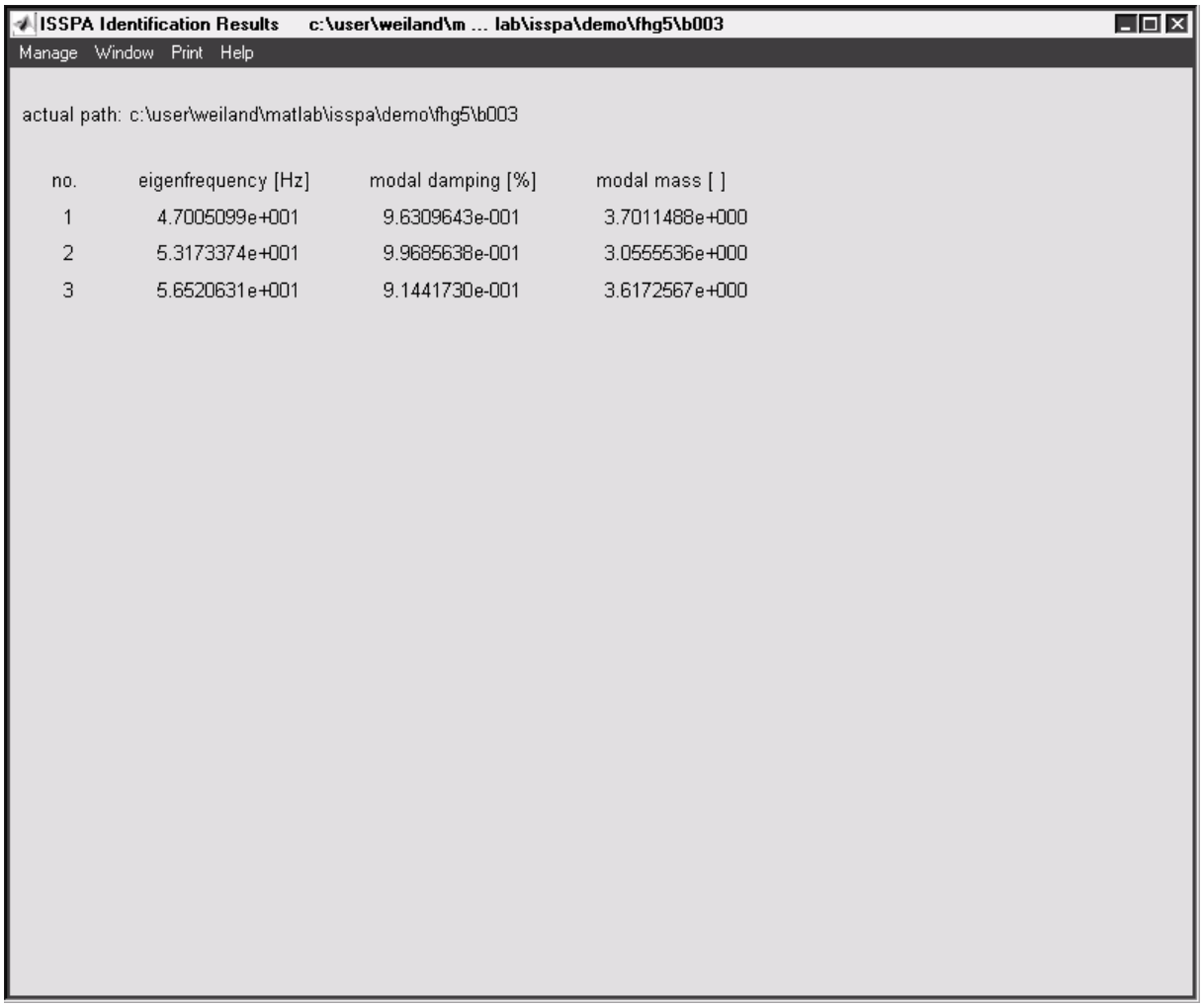
Buttons:

create fuelleis.ein	Create/Modify fuelleis.ein
.ein, .aus, disp_all	Edit fuelleis.ein, fuelleis.aus, type fuelleis.aus on MATLAB command window
add residuals	add residual terms from existing identification subdirectories
create	Create residual terms after identification from the deviation of measured and recalculated response
delete	Delete residual terms
Purge	Delete ISSPA intermediate results
main, start, tools, ctr lin, cmb, plot, id-log, list	Switch ISSPA window

Fig. 6.1.7: *ISSPA Combine Identification* window

ISSPA Identification Process c:\user\weiland\m ... lab\isspa\demo\fhg5\b003
Window Print Help
ISSPA02_01_b001 UKL Root Edition

Fig. 6.1.8: ***ISSPA Identification Process Log*** **window**
--- for development use only ---


ISSPA Identification Results c:\user\weiland\m ... lab\isspa\demo\fhg5\b003
Manage Window Print Help
actual path: c:\user\weiland\matlab\isspa\demo\fhg5\b003
no. eigenfrequency [Hz] modal damping [%] modal mass [ ]
1 4.7005099e+001 9.6309643e-001 3.7011488e+000
2 5.3173374e+001 9.9685638e-001 3.0555536e+000
3 5.6520631e+001 9.1441730e-001 3.6172567e+000

List modal parameters of actual working directory:

- eigenfrequencies (Hz)
- modal damping factors (Percent of critical damping), diagonal terms of the damping matrix
- modal masses w.r. eigenvectors normalized to 'max. value equal 1'

Fig. 6.1.9: *ISSPA Identification Results* window

6.2 Getting Started

It is recommended to use the following steps for an ISSPA identification of a measurement data set.
The data set will in general not be identified in one single identification run. Therefore a set of subdirectories must be allocated which should be organized and named as follows

\data measurement data file
\b001 first identification subdirectory

All other subdirectories will be created automatically in step 7.

All necessary steps will be illustrated by the data of the *garteur* example. The complete *garteur* example is given on the *demo\garteur* directory. The user can autorun this example by pressing *garteur* within MATLAB from the demo\garteur\autorun directory. It is recommended that prior to program execution the user should copy the complete demo directory to a temporary working directory to keep the original demo directory save.
Additional demonstration examples are given in the *demo* directory which can be started accordingly. These examples demonstrate different identification types and the application of the different measurement data formats.

Step1: Create subdirectories \data and \b001

example:
ISSPA identification parent directory: D:\project\isspa\garteur

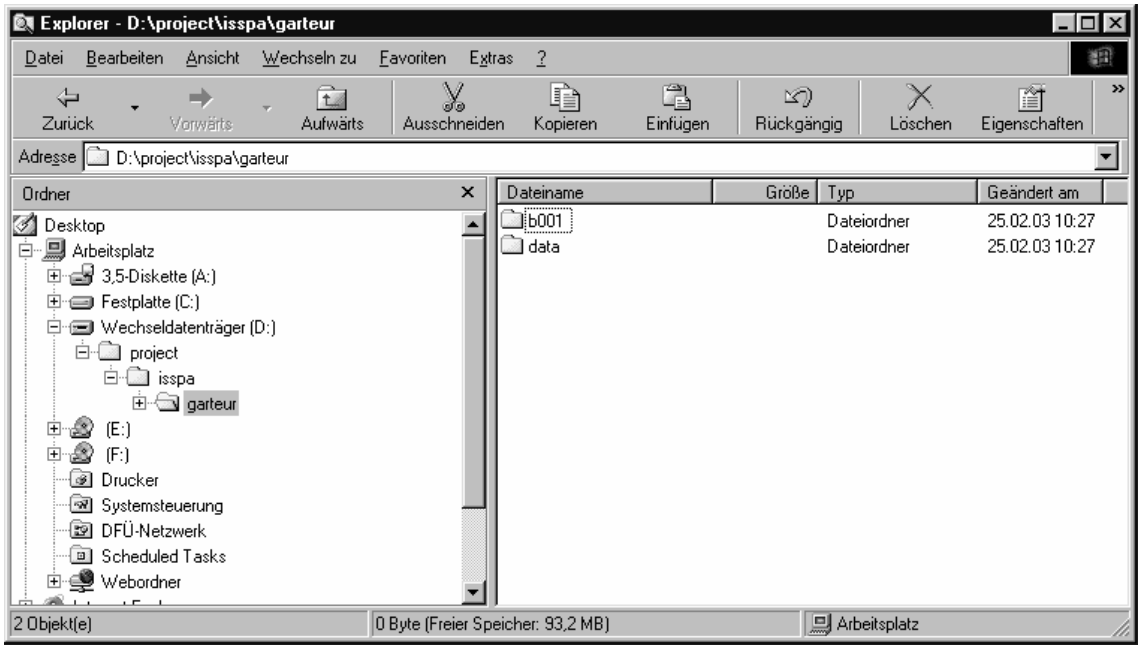


Fig 6.2.1: Create *subdirectories \data and \b001*

Step2: Start ISSPA within MATLAB

Step2.1 Press *isspa* within MATLAB

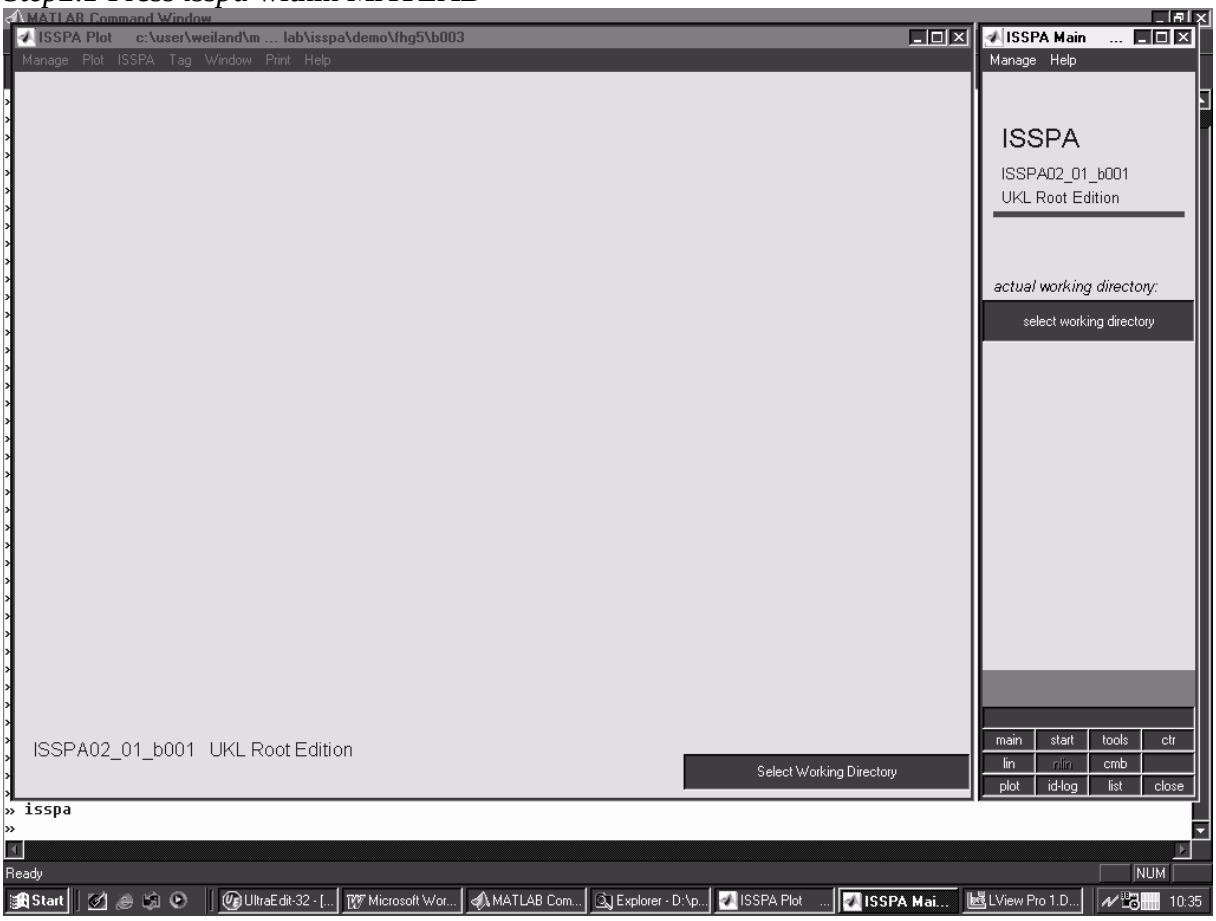


Fig 6.2.2: Start ISSPA within MATLAB. The *ISSPA Plot* window and the *ISSPA Main* window become accessible

Step3: Copy the measurement data to directory \data
If required convert the data file format

It is assumed that a file of measurement data is available from test. This file must be of type
UKL FR3 (app. A)
UKL UR3 (app. A)
UKL IDX (app. A)
MATLAB mat file (app.A)
SDRC Universal files, Type 58
Refer to app. 1 for detailed information about the data formats

The user can convert the original data set from
unv->ur3 Convert Universal File Type 58 to UKL UR3 File
unv->mat Convert Universal File Type 58 to MATLAB mat File
using the appropriate buttons of the *ISSPA Tools* window. If the original data set is none of these types the user must write a special program to convert the actual data format to a type which is supported by ISSPA (e.g. /12/). It is strongly recommended to use MATLAB m file programming for this task. Special MATLAB m files are available to easily write and check a proper UKL FR3 file (*writefr3, readfr3)* which then can be converted from formatted to unformatted UKL UR3 file (*formum).* Best performance can be expected if the data is available as a UKL UR3 file. Most internal data flow is performed using this file format. But care should be taken with this file format if the data is to be transferred between different operating systems like WINDOWS and UNIX because unformatted files are not exchangeable due to the different data representation. The UR3 files can be converted to FR3 at any time using *formum* .

example:
data directory:
D:\project\isspa\garteur \data
data file:
D:\project\isspa\garteur \data\man_12z.unv
Type: SDRC Universal files, Type 58

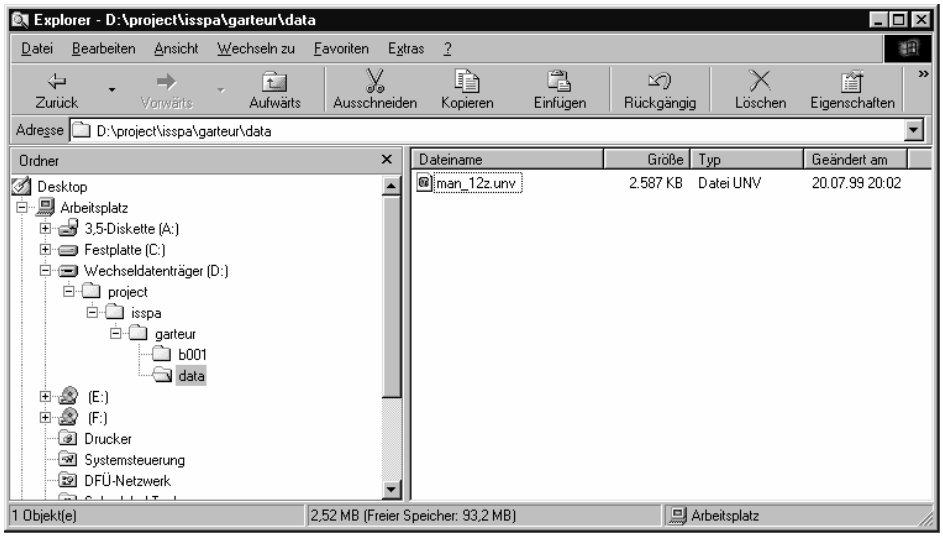
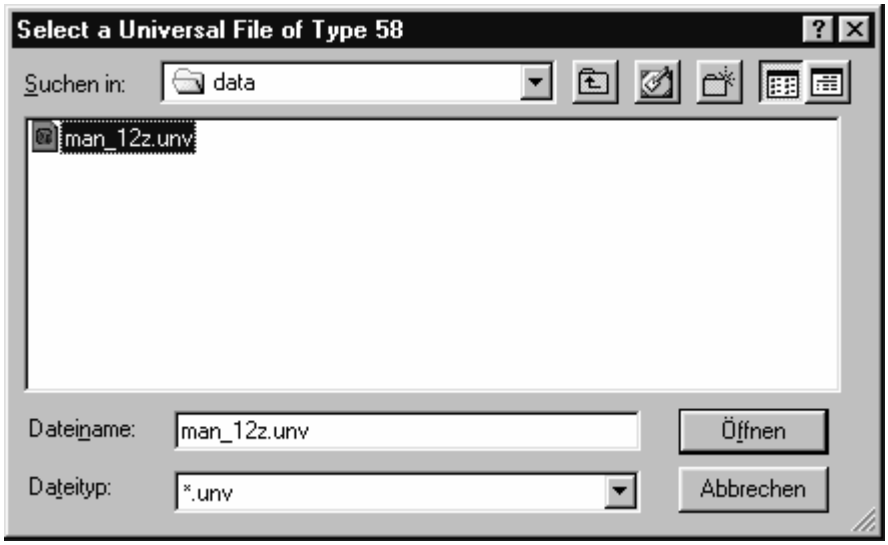


Fig 6.2.3: Copy data file to \data

Convert Universal File Type 58 to UKL UR3 File:
button unv->ur3 (ISSPA Tools window)



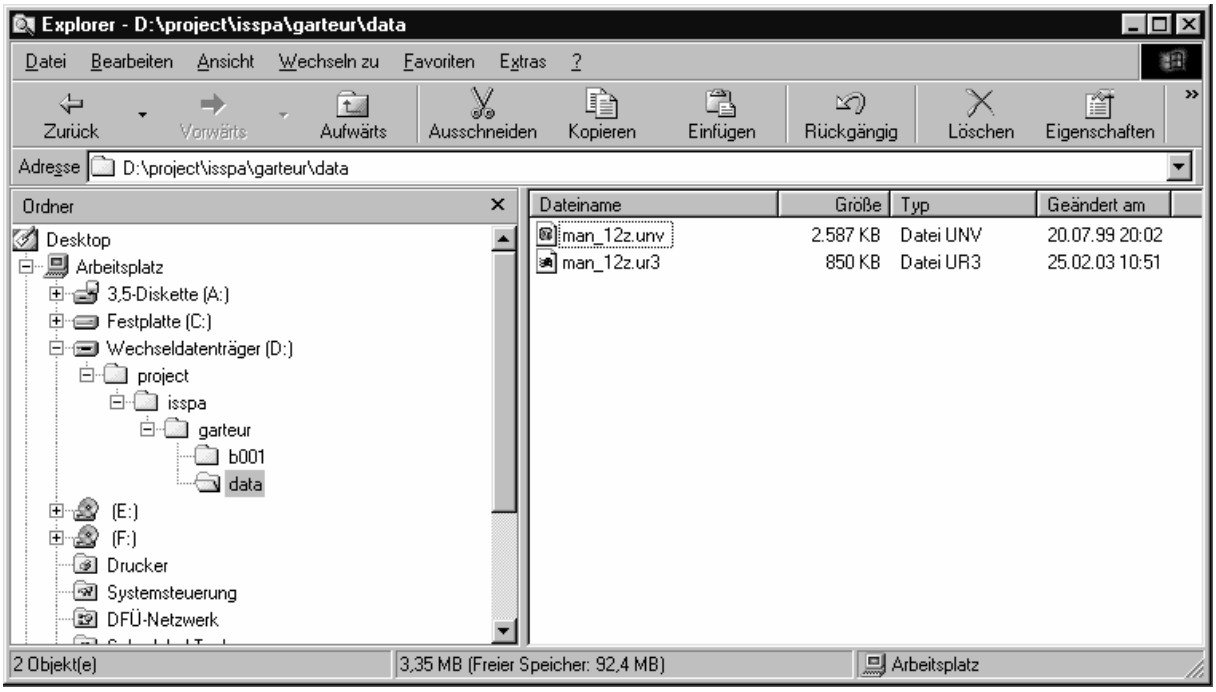


Fig 6.2.4: Convert Universal File Type 58 to UKL UR3 File

Step4: Change the ISSPA working directory to \b001

To change the ISSPA working directory use either the buttons of the *ISSPA Plot* window and the *ISSPA Main* window or the pulldown menu *Manage*, *fig 5.1.2*

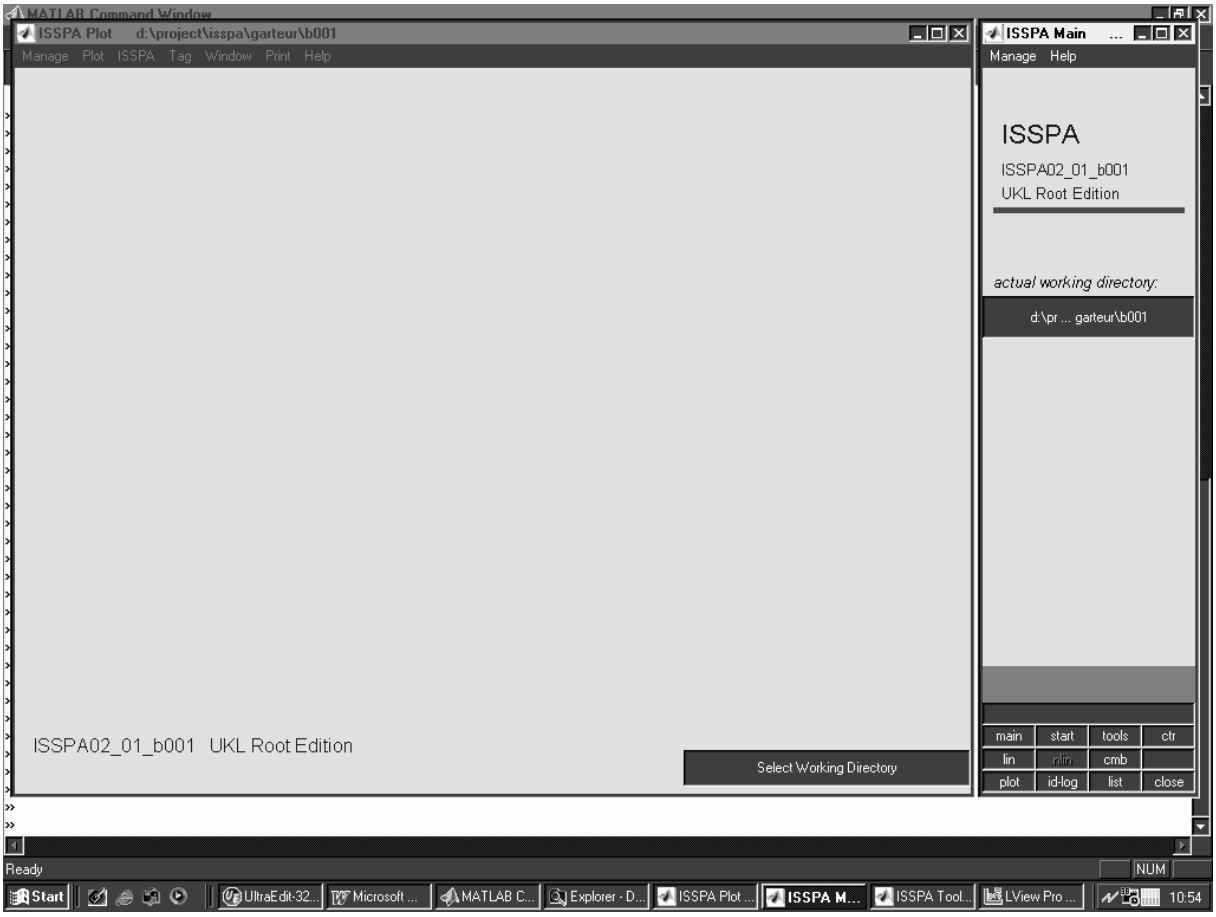


Fig 6.2.5: The *ISSPA Plot* window and *ISSPA Main* window

Step5: Create ispmod.ein in subdirectory \b001

To create an ispmod.ein file use the *create ispmod.ein* button of the *ISSPA Start* window,

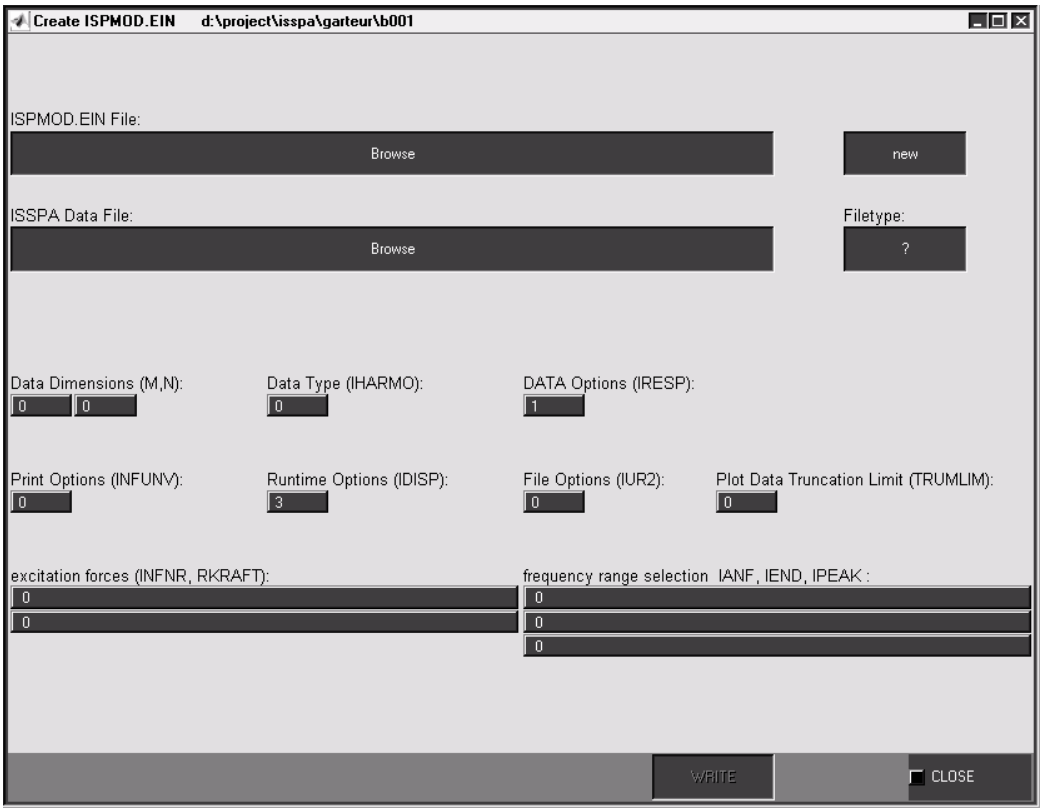


Fig 6.2.6: The *Create ispmod.ein* window to create/modify the ispmod.ein file

The user must carefully fill out this template

ISPMOD.EIN File press the *New* button to select the location of the ispmod.ein file (if the ispmod.ein file already exists, use the *Browse* button)

ISSPA Data File press the *Browse* button to select the data file D:\project\isspa\garteur \data\man_12z.unv

Filetype the filetype is set automatically set by ISSPA

Data Dimensions

M overall number of spectral lines, M= 4096

N overall number of MDOF, N= 24

Data Type (IHARMO) measurement data is FRF data: single point excitation

Data Options (IRESP) if data file is of type UNV:
IRESP = 0 response fixed
IRESP = 1 response moving

Print Options (INFUNV) if data file is of type UNV:
INFUNV = 1 list FRF header in ispmod.aus
INFUNV = 0 no listing of FRF header in ispmod.aus

File Options (IUR2) Create UKL UR2 plot files
IUR2 = 1 create*Runtime Options (IDISP)* Amount of runtime display
IDISP = 0 none
IDISP = 1 errors
IDISP = 2 errors/warnings
IDISP = 3 all

Plot Data Truncation Limit (ITRUNLIM)

excitation forces

INFNR	MDOF number	INFNR = 4
RKRAFT	force amplitude	FRF $\Rightarrow$ RKRAFT = 1.0

frequency range selection frequeny range limits

IANF	spectral line number left, (IANF = 1)
IEND	spectral line number right (IEND= 4096)
IPEAK	spectral line number of peak frequency, if automatic frequency line reduction is required. IPEAK= 0 no spectral line reduction

After supplying all needed input the user must press *write* to store the actual settings.

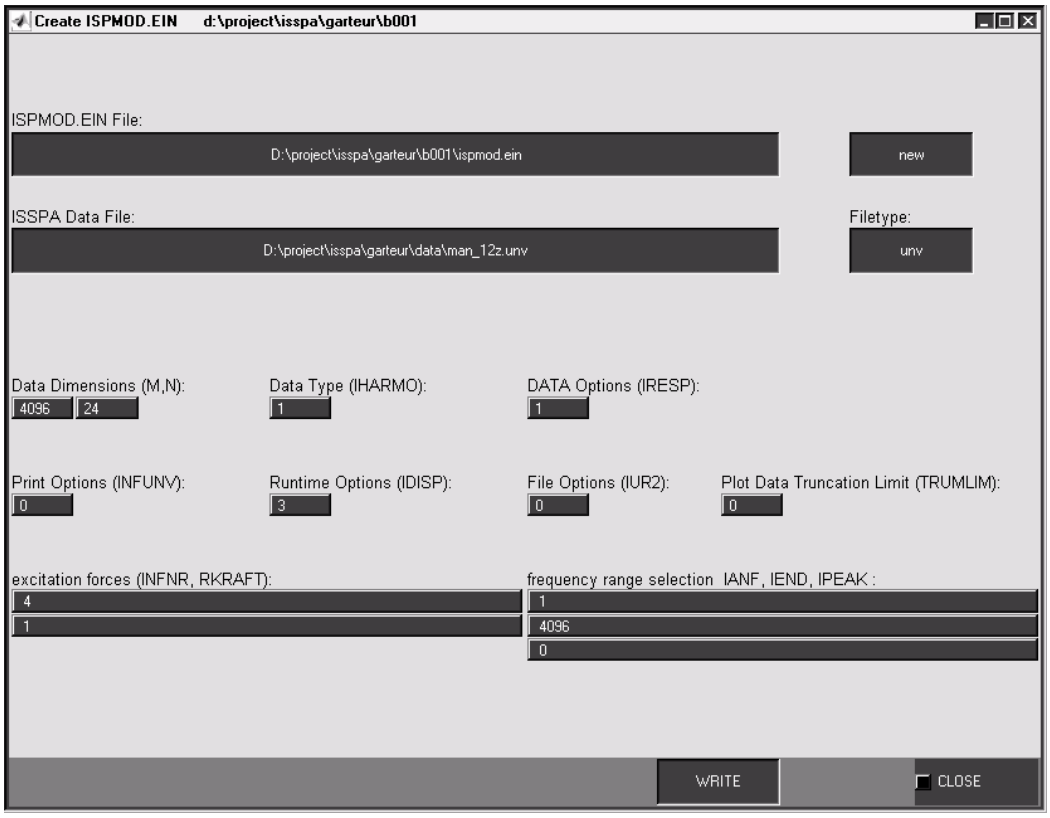


Fig 6.2.7: Setting of the ispmod.ein file

The user may also edit the ispmod.ein file. This ASCII file is of type UKL FR3.
To close the *Create ISPMOD.EIN* figure press *close*.

Step6: Create fitkor.ein in subdirectory \b001

To create a fitkor.ein file use the *create fitkor.ein* button of the *ISSPA Start* window

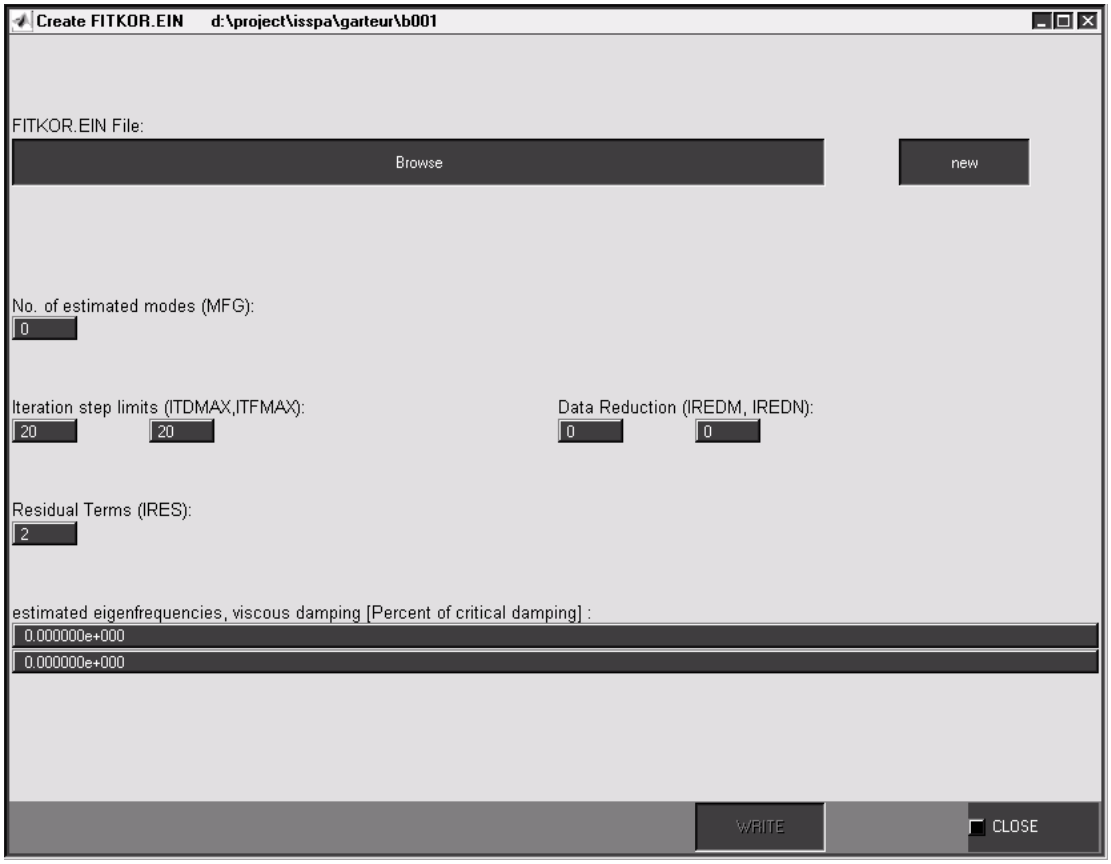


Fig 6.2.8: The *Create fitkor.ein* window to create/modify the fitkor.ein file

The user must carefully fill out this template:

FITKOR.EIN File press the *New* button to select the location of the fitkor.ein file (if the fitkor.ein file already exists, use the *Browse* button)

No. of estimated modes(MFG)

Iteration step limits

ITDMAX ITDMAX = 0 no damping iteration
ITDMAX = 20 max. 20 damping iteration steps, recommended

ITFMAX ITFMAX = 0 no eigenfrequency iteration
ITDMAX = 20 max. 20 eigenfrequency iteration steps (recomm.)

Data Reduction

IREDM IREDM = 1 5 spectral lines to the left and right of the estimated eigenfrequencies are used at the first iteration steps. Finally all spectral lines are used, if the iteration converges.

IREDN reserved

Residual Terms

IRES	IRES = 1 residual displacement *only* IRES = 2 residual displacement, residual acceleration IRES = 2 residual acceleration *only*

estimated eigenfrequencies
viscous damping[Percent of critical damping]
input of MFG estimated eigenfrequencies and
viscous damping factors

After supplying all needed input the user must press *write* to store the actual settings.

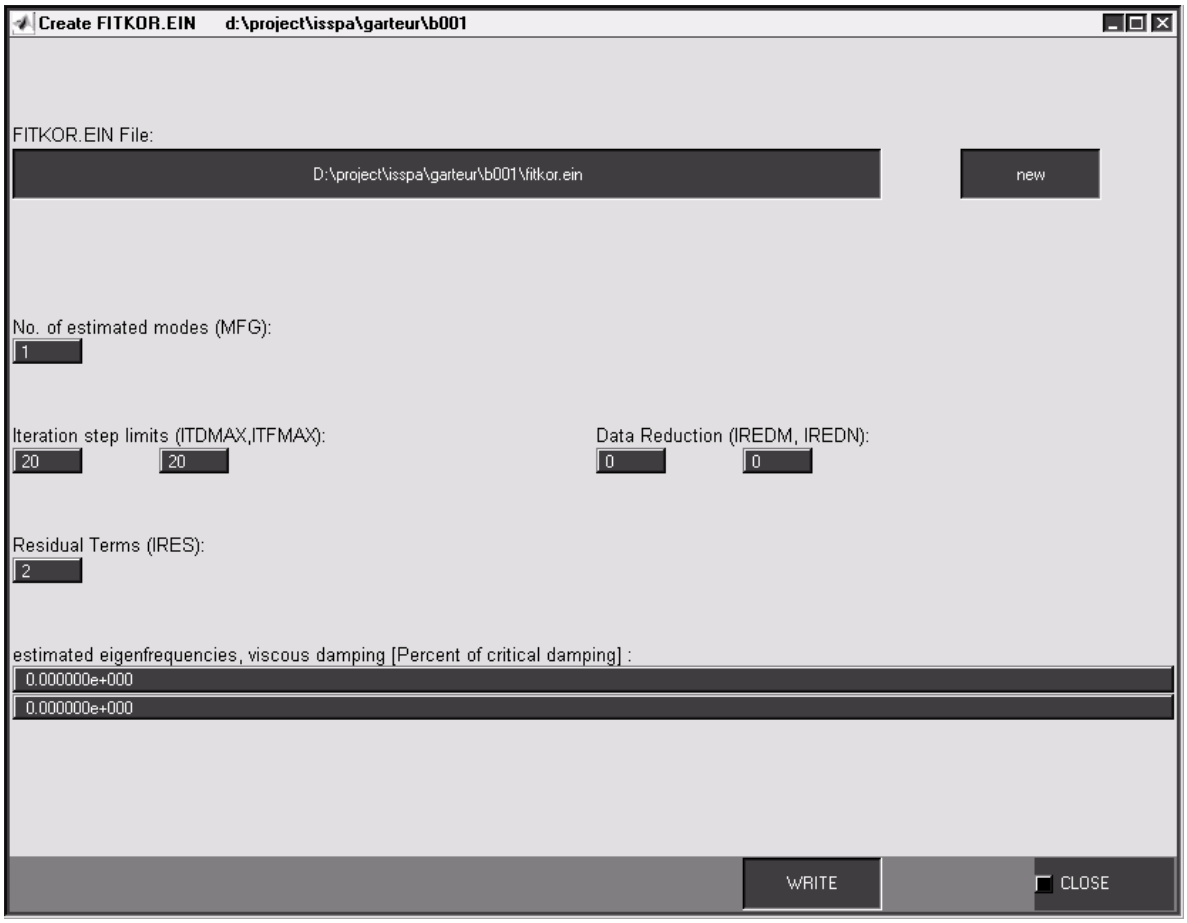


Fig 6.2.9: Setting of the fitkor.ein file

The user may also edit the fitkor.ein file. This ASCII file is of type UKL FR3.
To close the *Create FITKOR.EIN* window press *close*.

Step7: Create ISSPA identification subdirectories \b001 ...\b0xx, \bcmb

To create ISSPA identification subdirectories \b001 ...\b0xx, \bcmb use the *create ISSPA subdirs* button of the *ISSPA Start* window

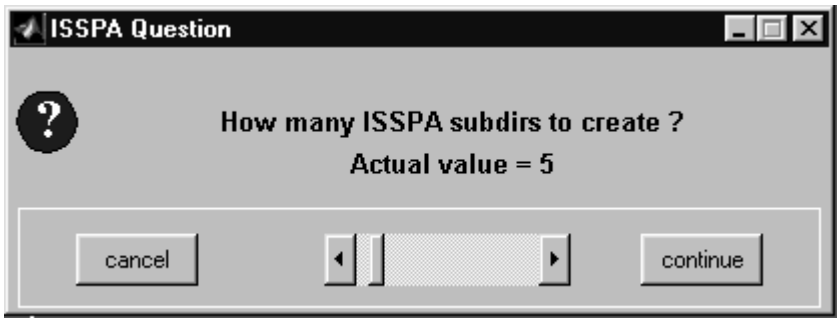


Fig 6.2.10: Select Number of ISSPA subdirectories to create

Use the slider to change the overall number of ISSPA subdirectories to create

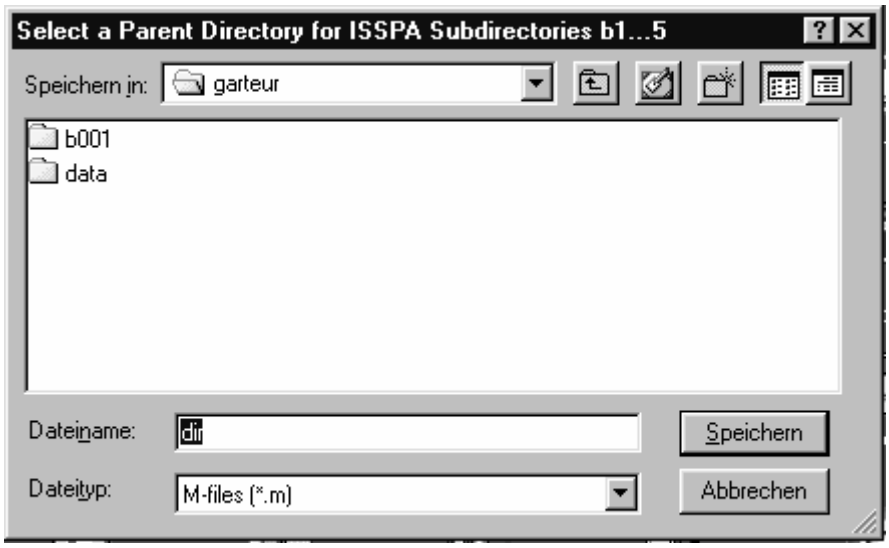


Fig 6.2.11: Select the parent directory of the ISSPA identification subdirectories \b001 ...\b0xx, \bcmb

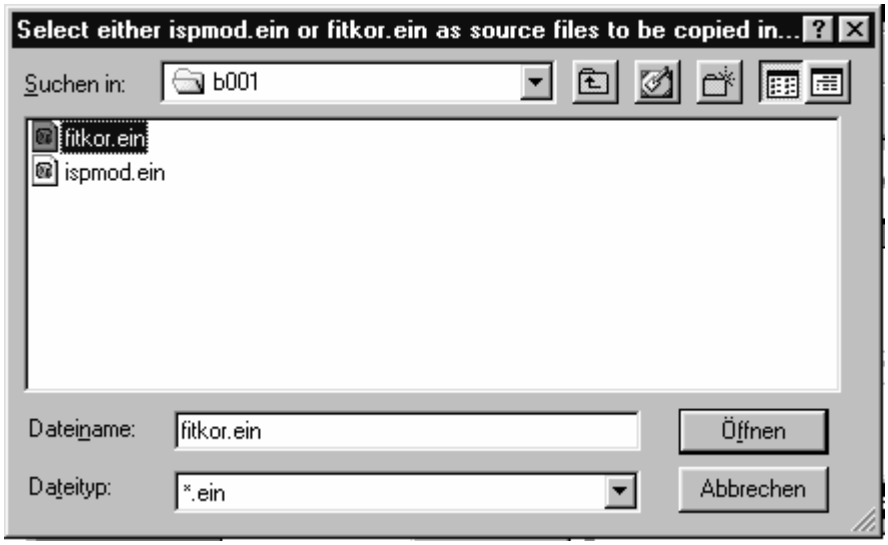


Fig 6.2.11: Select either ispmod.ein or fitkor.ein file to be copied into the ISSPA identification subdirectories \b001 ...\b0xx, \bcmb

The ispmod.ein, fitkor.ein and, if exist, is2tdas.ein files of the selected directory are copied into the ISSPA identification subdirectories \b001 ..\b0xx.
The ispmod.ein and, if exist, is2tdas.ein are copied to the \bcmb directory as well.

If any of the subdirectories and the respective input files exist the user will be notified. He will get detailed information on the *MATLAB command* window and he will be asked to keep or overwrite the respective subdirectories and files. If the user presses the 'yes to all' button ISSPA will automatically overwrite all existing subdirectories/files

After copying all data the user will be notified

Fig 6.2.12: ISSPA identification subdirectories successfully created

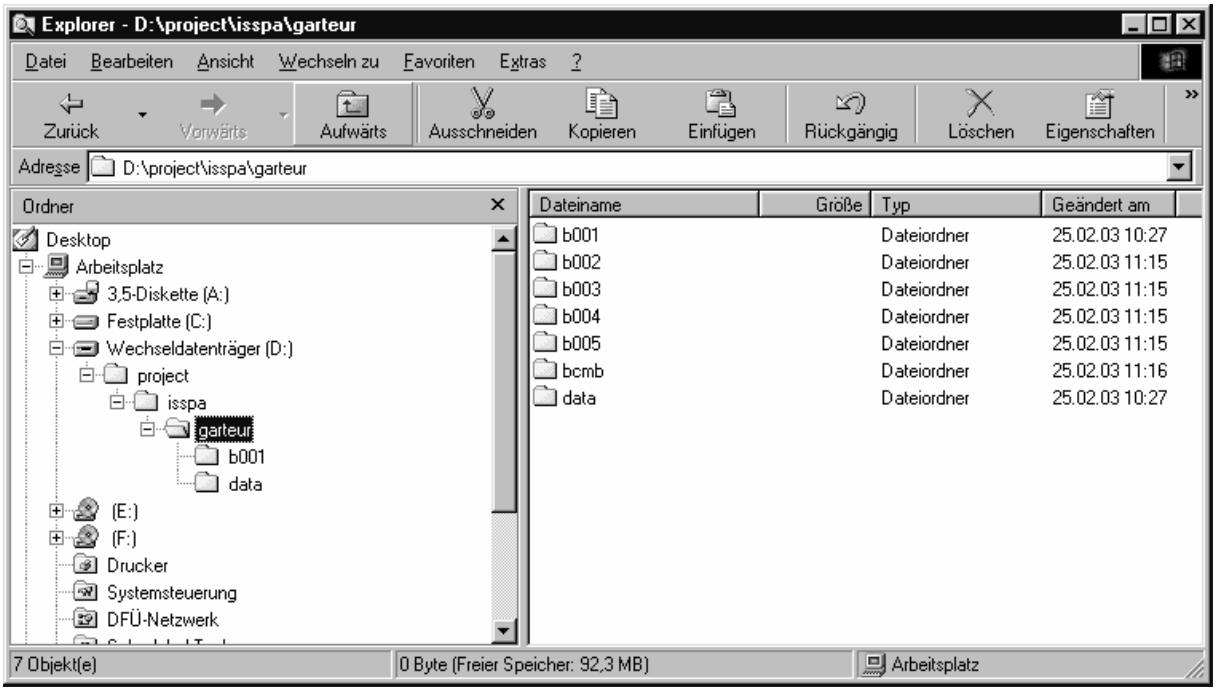


Fig 6.2.13: ISSPA identification subdirectories

Step8: Create fuelleis.ein in subdirectory \bcmb

To create a fuelleis.ein file use the *create fuelleis.ein* button of the *ISSPA cmb* window

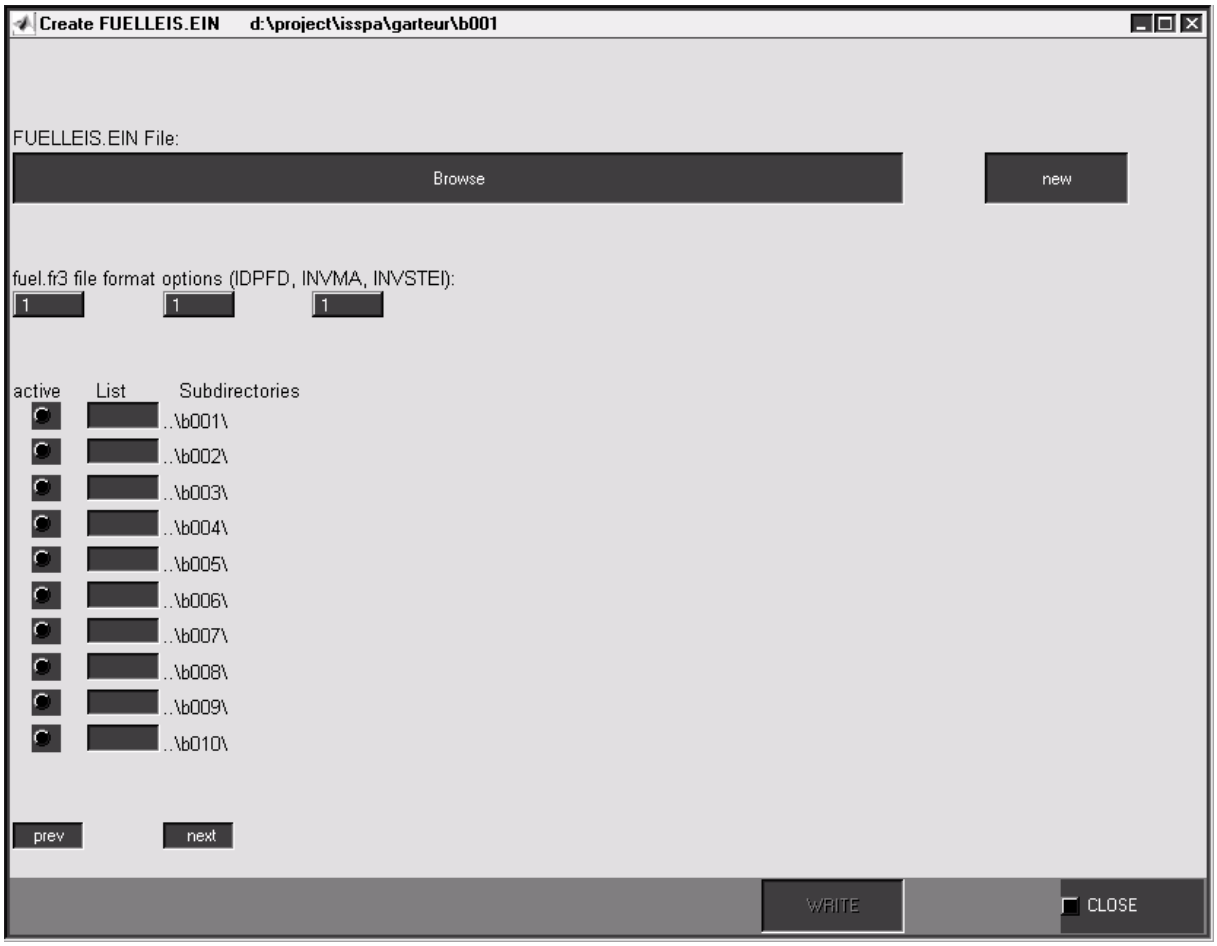


Fig 6.2.14: The *Create fuelleis.ein* window to create/modify the fuelleis.ein file

The user must carefully fill out this template:

FUELLEIS.EIN File	press the *New* button to select the location of the fuelleis.ein file (if the fuelleis.ein file already exists, use the *Browse* button)
fuel.fr3 format options	
IDPFD	IDPFD = 0 save complete modal damping matrix IDPFD = 1 save diagonal of modal damping matrix
INVMA	INVMA = 1 assemble and save inverse mass matrix
INVSTEI	INVSTEI = 1 assemble and save inverse stiffness matrix
active	select/deselect ISSPA identification subdirectory
list	list actual results of the ISSPA identification subdirectory
prev, next	scroll ISSPA identification subdirectories

After supplying all needed input the user must press *write* to store the actual settings.

Fig 6.2.15: Select directory of fuelleis.ein file

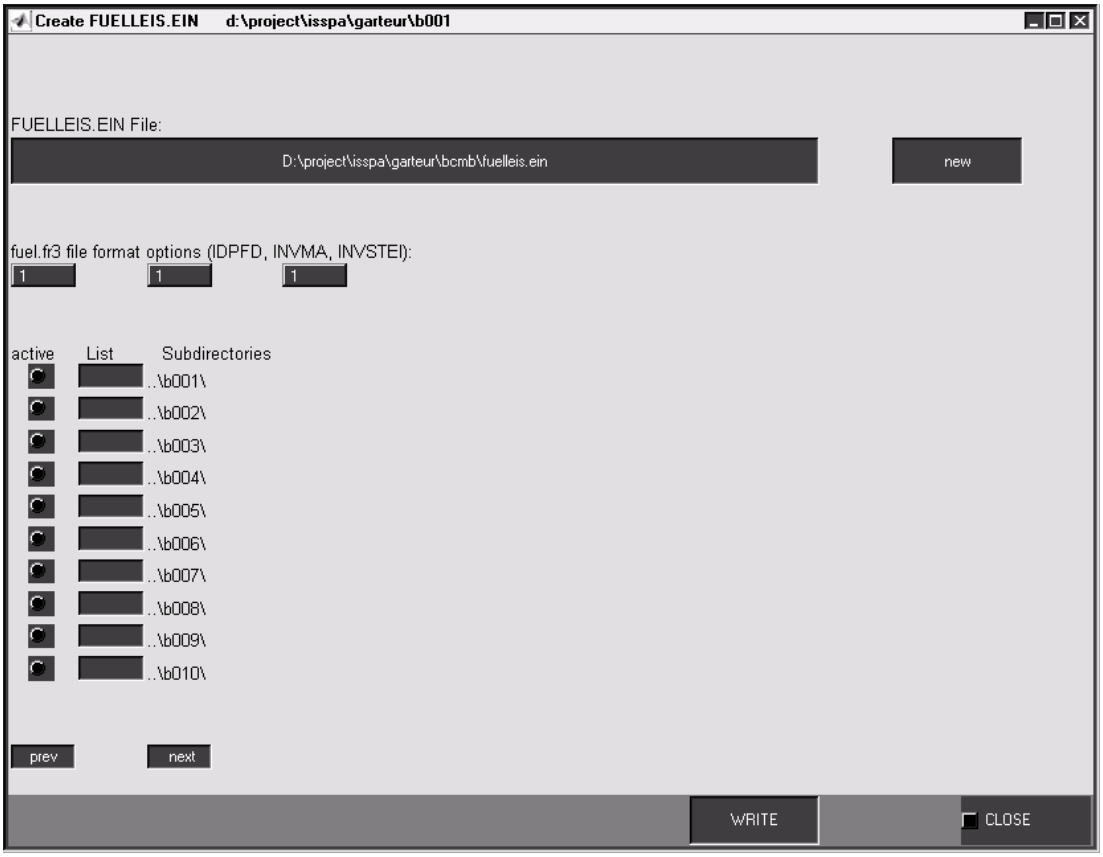


Fig 6.2.16: Setting of the fuelleis.ein file

The user may also edit the fuelleis.ein file. This ASCII file is of type UKL FR3.
To close the *Create FUELLEIS.EIN* figure press *close*.

Step9: View measurement data and mode indicator functions of the complete data set

Step 9.1: Change the ISSPA working directory to \b005
Step 9.2: Start ISPMOD from the *ISSPA Linear Identification* window
Step 9.3: Press plot to view the measurement data

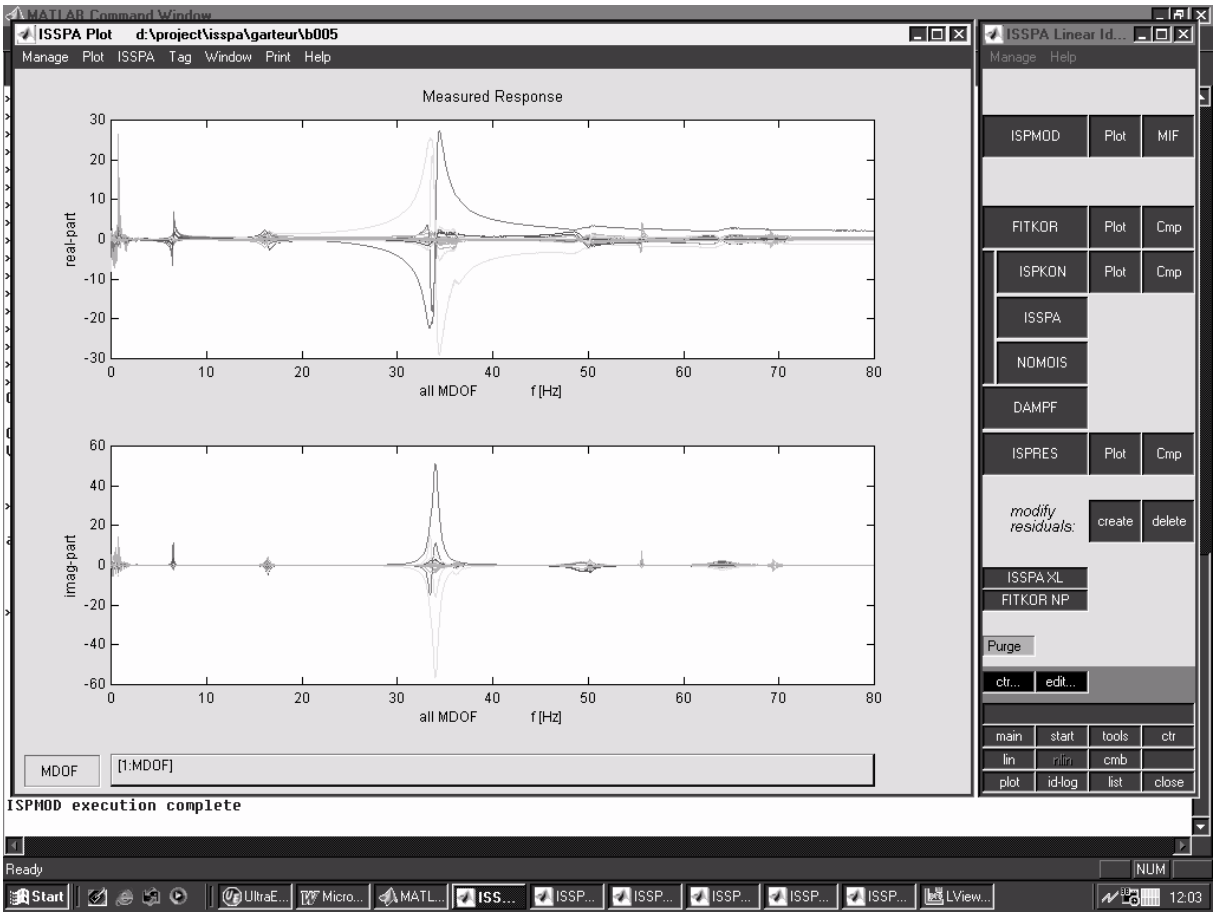


Fig 6.2.17: View measurement data

Step 9.4: Press MIF to view the mode indicator functions

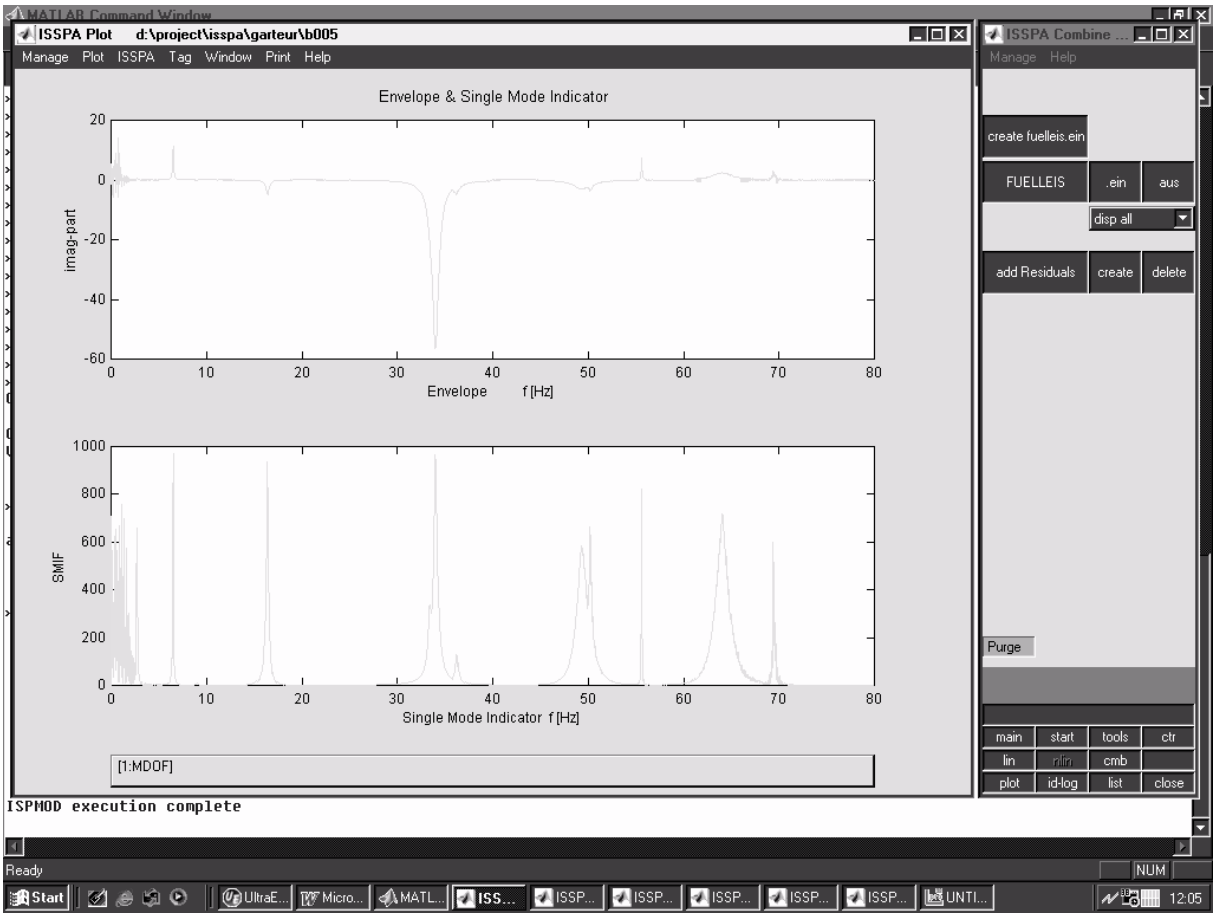


Fig 6.2.18: View mode indicator functions

Step 9.5 Save MIF plot to select identification ranges
ISSPA Plot pulldown menu:
Keep Figure
Parameter, lower subplot only

Note:
Window name *ISSPA PLOT* is changed to *Figure No 1: ISSPA Plot...*
(lower plot of fig. 6.2.19)

Step10: identify first mode in subdir \b001

Step 10.1 Change the ISSPA Working Directory to \b001
Step 10.2 Select identification range around first eigenfrequency
from *Figure No 1: ISSPA Plot...* window
ISSPA, Select identification ranges

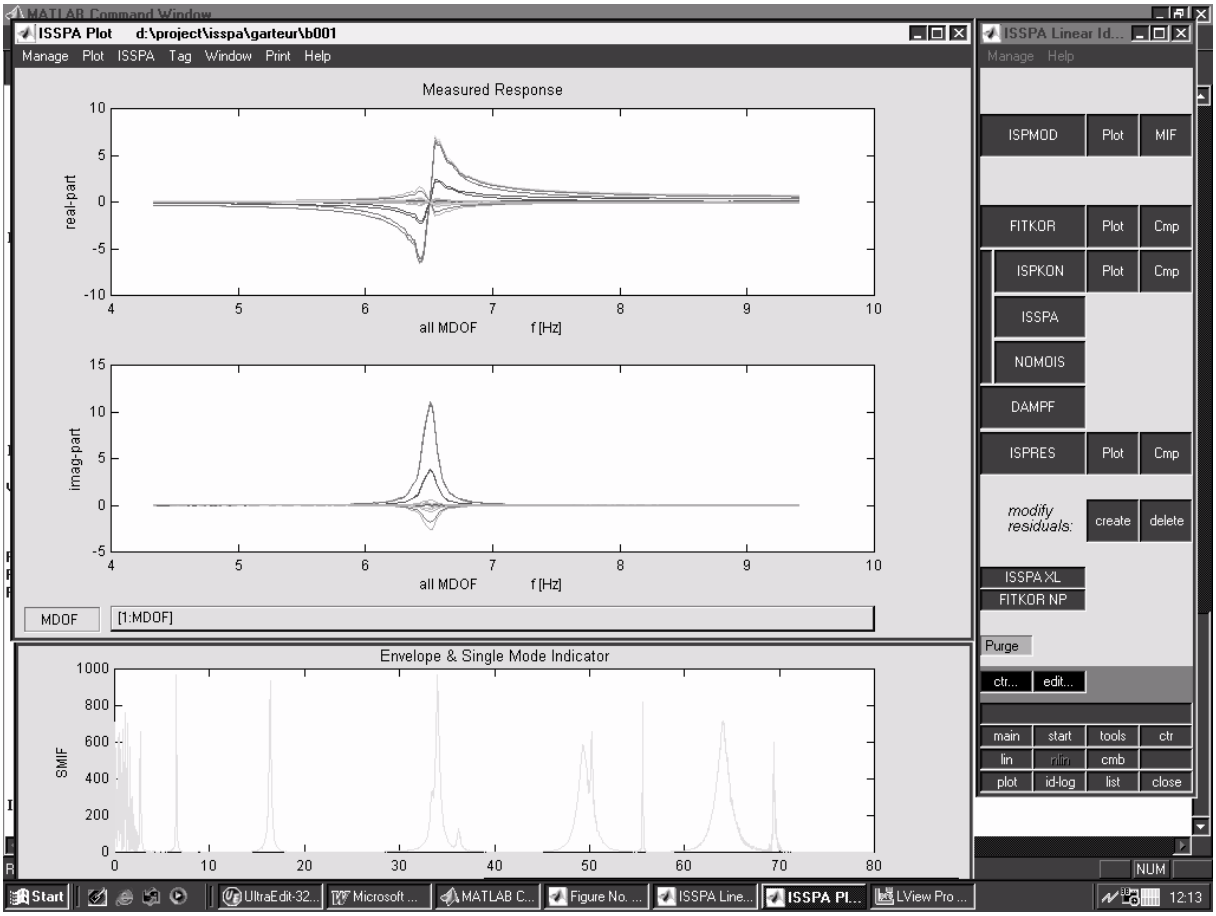


Fig 6.2.19: Select identification range near first eigenfrequency

Step 10.3 FITKOR identification

Pick Eigenfrequency in ISSPA Plot

ISSPA, Pick Eigenfrequencies

After Picking the first eigenfrequency FITKOR is automatically started

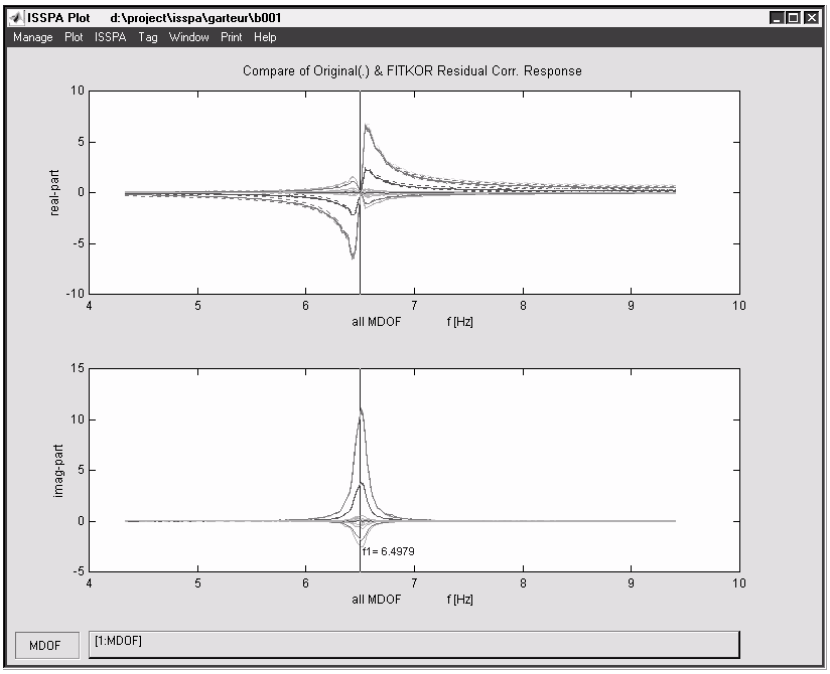


Fig 6.2.20: FITKOR identification

Step 10.4 Check FITKOR identification results

Press *Run ISPRES in the ISSPA pulldown menu*

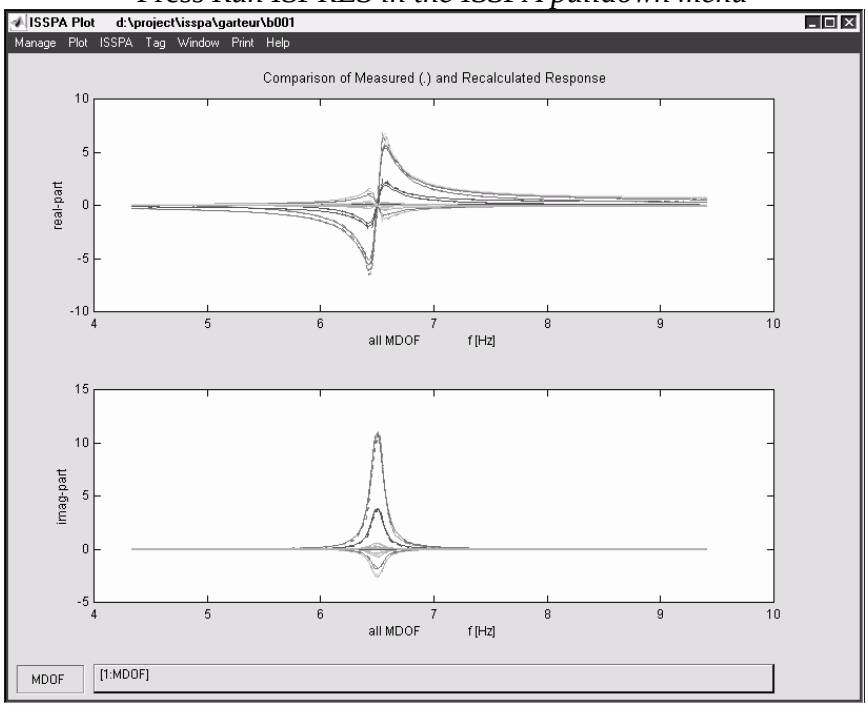


Fig 6.2.21: Check of FITKOR identification results

Step 10.5 ISSPA identification

Press *Run ISSPALL in the ISSPA pulldown menu*

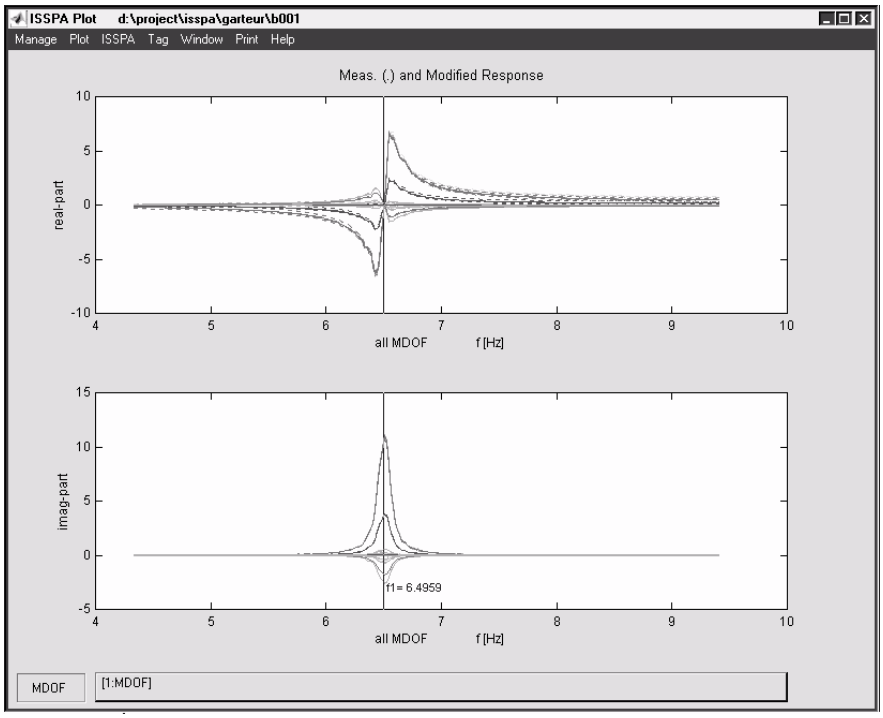


Fig 6.2.22: ISSPA identification results

Step 10.6 Check ISSPA identification results

Press *Run ISPRES in the ISSPA pulldown menu*

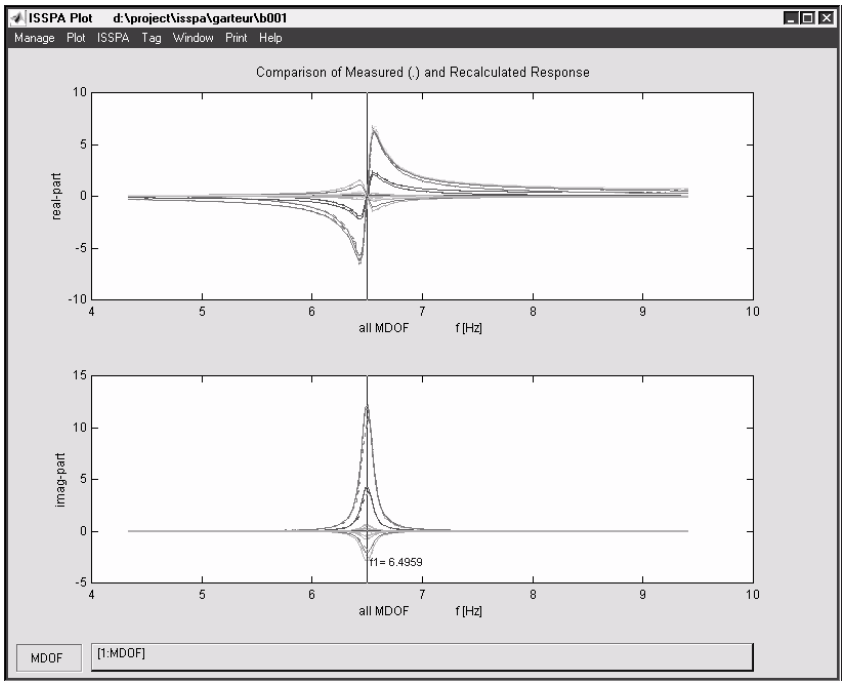


Fig 6.2.23: Check of ISSPA identification results

Step11: identify all other modes in subdir \b002 ...

repeat all substeps of step 10 to identify all modes of the measurement data set

Step12: combine ISSPA identification subdirectories \b001 ... \b0xx in subdirectory \bcmb

It is assumed that the complete data set was identified using the three ISSPA identification subdirectories \b001 ... \b003

Step 12.1: Change the ISSPA working directory to \bcmb

Step 12.2: Edit fuelleis.ein to select the subdirectories \b001 ..\b003

Press *Create fuelleis.ein* of the *ISSPA Main* window

Press radio buttons of \b001 ...\b003 to select the subdirectories

Press *save* to store actual settings

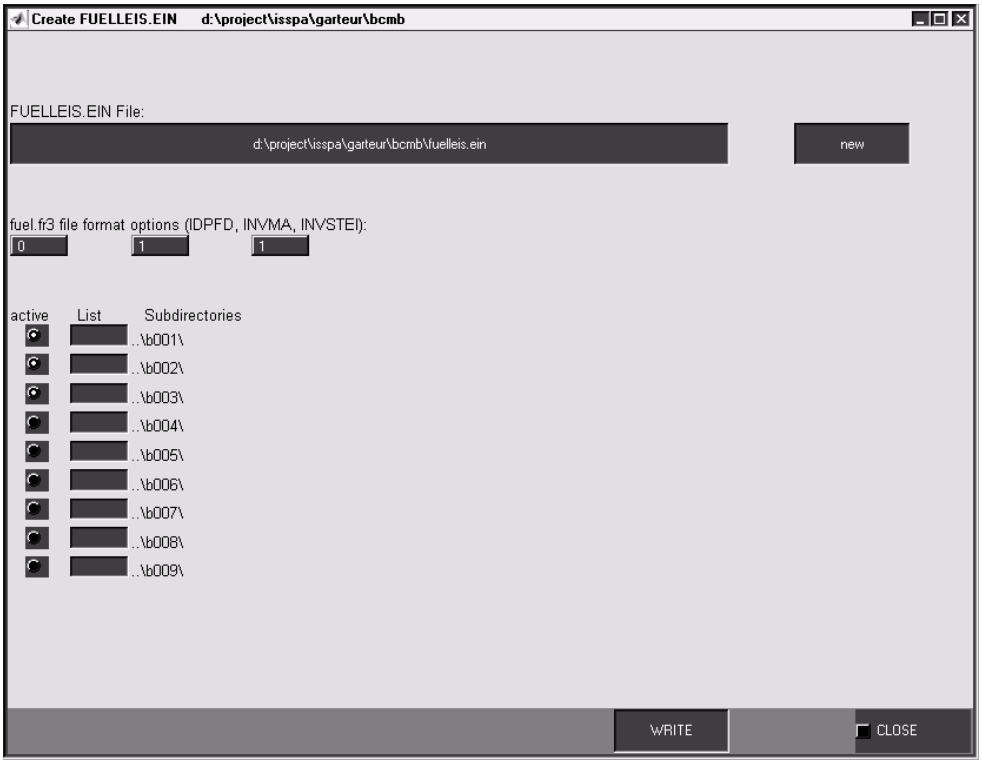


Fig 6.2.24: Select subdirectories \b001 ..\b003 They are used to assemble the overall identification results file fuel.fr3

Step 12.3: Press *fuelleis* to run FUELLEIS

Step13: Calculate response data using the combined modal data set

Step 13.1: Press *ispmod* from the *ISSPA Linear Identification* window to run ISPMOD
Step 13.2: Press *ispres* from the *ISSPA Linear Identification* window to run ISPRES
Step 13.3: Press *cmp* of *ispres* to view the comparison of measured and recalculated response

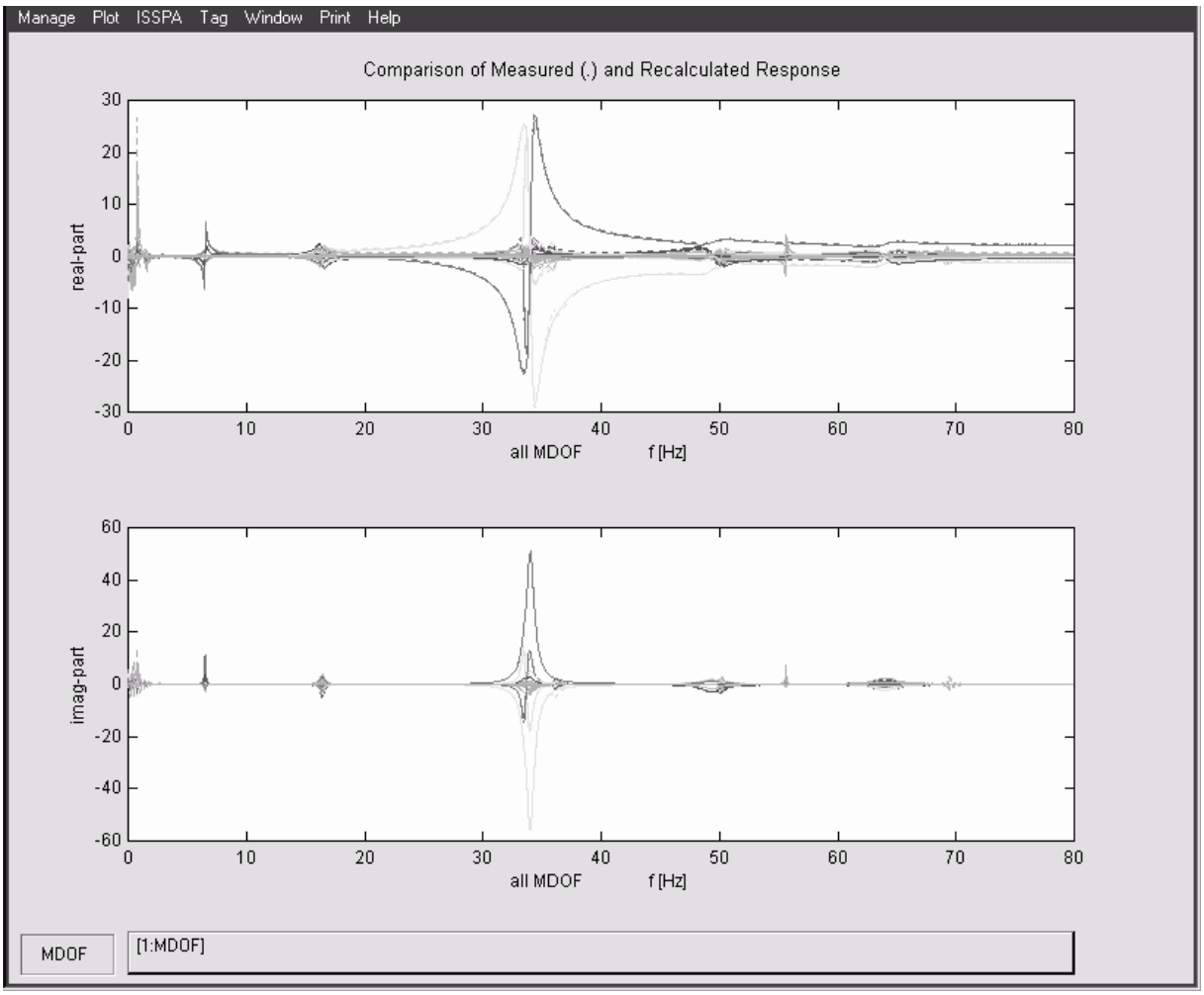


Fig 6.2.25: View the comparison of measured and recalculated response. The recalculated response was calculated using the combined identification results

7. ISSPA Main Results Files

The identification results of each identification subdirectory are stored in UKL FR3 data files

- nomo11.fr3 modal masses and damping matrix

- nomo12.fr3 real parts of the eigenvectors
  imaginary parts of the eigenvectors
  right hand modal matrix
  left hand modal matrix

- nomo13.fr3 inverse physical stiffness matrix
  (spectral synthesis, in general incomplete)

- nomo9.fr3 inverse physical mass matrix
  (spectral synthesis, in general incomplete)

Refer to app. A for detailed information about the UKL FR3 format.

If required, these data file can be read directly into MATLAB by using the readfr3 command.

example:

read eigenvalues (real, imaginary part) and right and left hand eigenvectors from the ISSPA data file *nomo12.fr3*

```
[lam_re, lam_im, Y,  X]= readfr3( 'nomo12.fr3')
```

If module FUELLEIS has been applied to combine several identification ranges the nomo11.fr3, nomo12.fr3, nomo13.fr3, nomo9.fr3 files contain the results of the combined modal data. In addition the file fuel.fr3 is created

- fuel.fr3 eigenfrequencies [Hz]
  modal masses
  modal damping matrix
  modal matrix(eigenvector by eigenvector)
  physical inverse mass matrix
  (spectral synthesis, in general incomplete)
  physical inverse stiffness matrix
  (spectral synthesis, in general incomplete)

If required, this data file can be read directly into MATLAB by using the readfr3 command.

```
[eigfreq, mue, xsi, phi, invM, invK]= readfr3( 'fuel.fr3')
```

Note: The modal matrix Φ is stored eigenvector by eigenvector i.e. Φ^T is stored.

example:

```
      6
 File  FUEL.FR3     created from module  FUELLEIS

       1       4R*4  eigenfrequencies  [ Hz ]
  0.6496132E+01  0.1635492E+02  0.3342412E+02  0.3398502E+02
       1       4R*4  modal masses
  0.4151932E+01  0.4419946E+01  0.7181810E+00  0.6889081E+00
       1       4R*4  diagonal of modal damping matrix [ Percent ]
  0.9389533E+00  0.1211294E+01  0.6741044E+00  0.1190145E+01
       4      24R*4  modal matrix (transposed, eigenvector by eigenvector)
  0.9961783E+00  0.9788201E+00 -0.3004567E-02  0.9712480E+00  0.2164015E-01
  0.3403399E+00 -0.3887944E-01  0.9964801E+00  0.1000000E+01  0.1242326E-01
  0.9955027E+00  0.1300680E-01  0.3474772E+00 -0.3537678E-01  0.9509832E-02
  0.1743245E-02 -0.2338367E+00 -0.1672707E+00  0.1111940E-02  0.6038030E-04
  0.5121520E-01 -0.6256211E-01  0.4697288E-01 -0.6422953E-01
 -0.4433073E+00 -0.4837220E+00  0.1392432E+00 -0.5305442E+00  0.8225252E-01
  0.1858084E+00  0.3741631E+00  0.4535891E+00  0.4970197E+00 -0.1481616E+00
  0.5321296E+00 -0.7900893E-01 -0.1779927E+00 -0.3722551E+00 -0.1768326E-05
 -0.1437991E-01 -0.5258517E-02  0.2225824E-02 -0.1869861E+00  0.1000000E+01
  0.1225540E-01  0.7815332E+00 -0.4834872E-01 -0.8335010E+00
 -0.1886097E+00  0.1060285E-01  0.1453784E-01  0.2052904E+00  0.1514559E-01
 -0.3442339E-01 -0.3644113E-01  0.1000000E+01  0.5018267E-01  0.2950925E-01
 -0.9275818E+00 -0.2108194E-01 -0.9619984E-02  0.1490270E-01 -0.1224379E-02
  0.1097076E-01  0.6956457E-02  0.1316239E-02 -0.6194564E-02  0.6055269E-01
 -0.2822213E-02  0.8184624E-01 -0.1373446E-01 -0.1025655E+00
  0.1000000E+01  0.4829212E-01  0.3005042E-01 -0.9103230E+00 -0.1975775E-01
 -0.1041523E-01  0.1635938E-01  0.3307970E+00  0.5121922E-01  0.4001315E-01
 -0.2341951E+00  0.1025470E-01 -0.5793894E-01 -0.4974201E-01 -0.1918605E-02
 -0.8239701E-02  0.1147643E-01  0.1912182E-02  0.2152015E-02 -0.5058206E-01
 -0.1045360E-01 -0.9565794E-01 -0.5013299E-02  0.6882320E-01
      24      24R*4  inverse mass matrix   (row by row)
  0.1784582E+01  0.3506804E+00  0.2511585E-01 -0.1089068E+01 -0.3571489E-01
  0.5694401E-01 -0.1353878E-01  0.4111475E+00  0.2512510E+00  0.6817310E-01
  0.8913288E-01  0.3146711E-01  0.1964661E-01 -0.4726983E-01 -0.1815625E-03
 -0.1298116E-01 -0.4074537E-01 -0.3792671E-01  0.2377156E-01 -0.1896085E+00
 -0.3374030E-02 -0.2537450E+00  0.1244929E-01  0.1950248E+00
  0.3506804E+00  0.2872380E+00 -0.1362605E-01  0.2262529E+00 -0.5061503E-02
   ...
 -0.6673619E-02  0.1873330E-01  0.2377561E-01  0.6364847E-01 -0.1635967E-03
  0.2948286E-03  0.4762087E-02  0.2170958E-02  0.3634376E-01 -0.2022791E+00
 -0.3744663E-02 -0.1676566E+00  0.9851424E-02  0.1796962E+00
      24      24R*4  inverse stiffness matrix   (row by row)
  0.1806364E-03  0.1470365E-03 -0.8851558E-06  0.1147140E-03  0.1616170E-05
  0.4712373E-04 -0.8415350E-05  0.1437794E-03  0.1406293E-03  0.4294511E-05
  0.1363841E-03  0.3075632E-05  0.4994640E-04 -0.3231501E-05  0.1315818E-05
  0.6000249E-07 -0.3330285E-04 -0.2405812E-04  0.2041526E-05 -0.1146013E-04
  0.6943534E-05 -0.1996569E-04  0.7146348E-05  0.1468075E-05
  0.1470365E-03  0.1436025E-03 -0.1817207E-05  0.1416077E-03  0.2184509E-05
  0.4620782E-04 -0.9366609E-05  0.1371530E-03  0.1364532E-03  0.3364921E-05
  0.1346868E-03  0.2668122E-05  0.5092345E-04 -0.1219600E-05  0.1342383E-05
  ...
 -0.1625624E-04  0.1380897E-05 -0.1437719E-06  0.6818987E-05 -0.8851293E-07
  0.1870318E-06  0.2267865E-05  0.1513406E-05  0.3353644E-05 -0.1816545E-04
 -0.7081912E-06 -0.1385029E-04  0.4607240E-06  0.1596397E-04
```

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